2017-06

Developing tools for mission engineering analysis during hurricane preparation and operations

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Monterey, California: Naval Postgraduate School

http://hdl.handle.net/10945/55584

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

DEVELOPING TOOLS FOR MISSION ENGINEERING ANALYSIS DURING HURRICANE PREPARATION AND OPERATIONS

by

Sean R. Christopherson

June 2017

Thesis Advisor:	Alejandro S. Hernandez
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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704–0188*

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** June 2017	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE
DEVELOPING TOOLS FOR MISSION ENGINEERING ANALYSIS DURING HURRICANE PREPARATION AND OPERATIONS

5. FUNDING NUMBERS

6. AUTHOR(S) Sean R. Christopherson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Marine Forces Reserve
2000 Opelousas Ave
New Orleans, LA 70114

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (maximum 200 words)

The Marine Forces Reserve Headquarters Training Centers (MFRHTC) located along the southeastern United States coastline must make timely and appropriate decisions regarding hurricane preparation operations when they are threatened by tropical cyclones. In response to a request from the Marine Forces Reserve Headquarters to help their MFRHTCs prepare, the Naval Postgraduate School and the Center for Educational Design, Development, and Distribution are developing a location specific hurricane decision simulator (HDS) for the MFRHTC in Hialeah, Florida. The purpose of this thesis is to identify the types of information and resources necessary for hurricane preparations operations and form a conceptual design for a database support system (DBSS) that will enable the required information to be collected, stored, and accessed by the HDS. Mission engineering analysis, systems engineering, and the military decision-making process are used to evaluate and analyze the information, resources, and decisions that the commander of the MFRHTC must make in preparation for a hurricane. The results of this thesis detail a conceptual design, functional baseline for the DBSS, specify the information and resources requirements for the DBSS, and illustrate the decision logic of the HDS for the MFRHTC in Hialeah.

14. SUBJECT TERMS
mission engineering, military decision making process, hurricane preparation operations, design methodology

15. NUMBER OF PAGES 105

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540–01-280-5500 Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

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DEVELOPING TOOLS FOR MISSION ENGINEERING ANALYSIS DURING HURRICANE PREPARATION AND OPERATIONS

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MASTER OF SCIENCE IN SYSTEMS ENGINEERING

from the

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ABSTRACT

The Marine Forces Reserve Headquarters Training Centers (MFRHTC) located along the southeastern United States coastline must make timely and appropriate decisions regarding hurricane preparation operations when they are threatened by tropical cyclones. In response to a request from the Marine Forces Reserve Headquarters to help their MFRHTCs prepare, the Naval Postgraduate School and the Center for Educational Design, Development, and Distribution are developing a location specific hurricane decision simulator (HDS) for the MFRHTC in Hialeah, Florida. The purpose of this thesis is to identify the types of information and resources necessary for hurricane preparations operations and form a conceptual design for a database support system (DBSS) that will enable the required information to be collected, stored, and accessed by the HDS. Mission engineering analysis, systems engineering, and the military decision-making process are used to evaluate and analyze the information, resources, and decisions that the commander of the MFRHTC must make in preparation for a hurricane. The results of this thesis detail a conceptual design, functional baseline for the DBSS, specify the information and resources requirements for the DBSS, and illustrate the decision logic of the HDS for the MFRHTC in Hialeah.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADVON	advanced echelon
ATCF	Automated Tropical Cyclone Forecasting System
C2	command and control
CED3	Center for Educational Design, Development, and Distribution
COA	course of action
DBSS	database support system
FFBD	functional flow block diagram
HDS	Hurricane Decision Simulator
HTC	headquarters training center
ICOM	inputs, controls and constraints, outputs, mechanisms
kts	knots
MARFORRES	Marine Corps Forces Reserve Headquarters in New Orleans
MDMP	Military Decision Making Process
MDOEM	Miami-Dade Office of Emergency Management
ME	mission engineering
MFRHTC	Marine Forces Reserve Headquarters Training Center
mph	miles per hour
NHC	National Hurricane Center
NPS	Naval Postgraduate School
OPORD	operations order
RBE	remain behind element
SE	systems engineering
SoS	system of system
TC	tropical cyclone
TPM	technical performance measure
U.S.	United States

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EXECUTIVE SUMMARY

The Marine Forces Reserve Headquarters Training Centers (MFRHTCs) located along the southeastern United States coastline must make timely and appropriate decisions in hurricane preparation operations when they are threatened by developing tropical cyclones (TCs). In response to a request from the Marine Forces Reserve Headquarters (MARFORRES) in New Orleans to help their personnel prepare for tropical cyclones, the Naval Postgraduate School and the Center for Educational Design, Development, and Distribution developed a hurricane decision simulator (HDS). This HDS was very successful and MARFORRES requested similar HDSs be built for their MFRHTCs located along the southeastern U.S. coastline. The MFRHTC in Hialeah, Florida just northwest of Miami was chosen as the pilot because historically Florida is extremely susceptible to TCs. Version one of the HDS was specific to MARFORRES headquarters and information was built into the programming code. The team needed a way to transform the HDS from its current version to a version that would enable it to be adaptable to new locations.

The purpose of this thesis is to identify the types of information, resources, and decisions necessary for hurricane preparation operations, develop a conceptual design for a database support system (DBSS) that will enable the required information to be collected, stored, and accessed by the HDS, and develop the DBSS for the MFRHTC in Hialeah, Florida.

Systems engineering, mission engineering analysis, and the military decision making process are powerful tools that can be used to examine the information and resource requirements and the decision and actions that the commander of a MFRHTC must make in hurricane preparation operations.

The information, resources, and decisions required during hurricane preparation operations were collected to complete the DBSS during two site visits, one to MARFORRES and the other to the MFRHTC. Several key decisions were identified that the MFRHTC must make during hurricane preparation operations. These decisions enabled the construction of a decision tree, which determined the decision logic and

architecture of the programming code. The key decisions that the commander of the MFRHTC in Hialeah must make include: 1) Prepare the advanced echelon (ADVON) party, 2) Storm proof the headquarters training center (HTC) and personal property, 3A) Deploy the advanced party to the alternate command and control location and authorize a voluntary evacuation, or 3B) Prepare and stand up the RBE, 4A) Secure the HTC and issue a mandatory evacuation order or 4B) Shelter in place, and 5) Transfer command and control to the alternate headquarters.

In creating a conceptual design for the DBSS, it was essential to understand the customer need as well as the functions and components associated with the DBSS. System planning and architecting lead to the development of a functional baseline for the DBSS. A functional analysis of the DBSS illustrated the specific functions and components required to build the DBSS. This lead to mapping the functions to components. A system trade-off and feasibility analysis was conducted resulting in two alternatives: 1) replacing the location specific information built into the programming code 2) removing the location specific information from the code and placing it in a storage location where the code referenced the information needed during a simulation. Alternative two was chosen because it is already a well-established practice in the software industry and allows for easier handling of the information. The DBSS operating requirements were determined using a mission and systems engineering approach to evaluate commonly listed seven areas: 1) mission definition, 2) performance and physical parameters, 3) operational deployment or distribution, 4) operational life-cycle, 5) utilization requirements, 6) effectiveness factors, and 7) environmental factors as identified by Blanchard and Fabrycky (2011). The DBSS requires a storage device to store the spreadsheets, a computer to run them, and periodic updates to the information in the DBSS. Lastly, an overall conceptual design for the DBSS is presented as part of a conceptual design review to ensure that the alternative design selected was correct and can progress to the next step, preliminary design.

Reference

Blanchard, Benjamin S., and Wolter J. Fabrycky, 2011. *Systems Engineering and Analysis*. 5th ed. Upper Saddle River, NJ: Prentice Hall International Series in Industrial and Systems Engineering.

ACKNOWLEDGMENTS

I would like to acknowledge the time and effort my thesis advisors, Dr. Alejandro Hernandez and Dr. Eva Regnier, have devoted to me and to this project. Their guidance and advice in dealing with a number of problems while researching and writing this thesis have been instrumental to the completion of this project. Both have devoted numerous hours of their time to editing and formulating the ideas and processes. I am grateful for their efforts.

I would also like to acknowledge the time and effort that was dedicated to this project by the staff at MARFORRES and the HTC in Hialeah, to include Lt Col Bob McGuiness, USMC (Retired), Mrs. Cathy Griffin, and Mr. Jose Garcia at MARFORRES and Col Jonathon Price, Capt Marshall Jones, and the rest of the staff in Hialeah. Their insights into hurricane preparation operations, work collecting data, and framing the problem were instrumental to the completion of this project.

I would also like to thank the CED3 team at NPS for its contributions to developing the HDS into a workable tool for the Marines in Hialeah. These efforts into the programming code were crucial to this project.

Lastly, and most importantly I would like to thank my wife, Gretchen, for making this thesis possible. She allowed me to spend countless hours on the computer and away from home, conducting research and writing this thesis while she took care of our daughter, Allison, and two dogs. Without her, I would not have been able to complete this project. From the bottom on my heart, I thank you.

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I. INTRODUCTION AND BACKGROUND

A. INTRODUCTION

When tropical cyclones and hurricanes are forecasted or active in the Gulf of Mexico, Caribbean Sea, or the Atlantic Ocean, the Commanders of the Marine Forces Reserve Headquarters Training Centers (MFRHTC) located along the southeastern United States coastline must make timely and appropriate decisions in preparation for possible evacuation and for continuity of operations in another location. In this situation, the commanders encounter ever-changing conditions where they must balance the safety of their personnel, facilities, and equipment when maintaining sustainable and effective operations. Achieving a balance of maintaining sustainable and effective operations requires a systematic exploration of the dynamics of military hurricane preparation operations along with the decisions and time involved (Comfort, Siciliano, and Okada 2011). While hurricane preparations activities, actions, and evacuations can be costly, failing to properly prepare and act accordingly when threatened by a TC could lead to potential loss of life and severe damage to facilities and infrastructure.

These commanders often make decisions under severe time constraints with information that changes by the hour, and the required actions from these decisions can have significant lead times. Additionally, the commanders and their staffs change every two to three years, often during peak hurricane season. Incoming personnel potentially have little to no experience living in an area susceptible to hurricanes. No matter when a potential storm or the personnel changeover occurs, the commanders are ultimately responsible for ensuring the safety and well-being of the personnel, equipment, and facilities while maintaining continuity of operations. This situation brings multiple dimensions of uncertainty about the potential impacts to the command, personnel, and facilities, which the commanders and staffs must navigate and make challenging decisions.

This thesis will focus on the MFRHTC located in Hialeah, Florida, and use it as a case study for developing future Hurricane Decision Simulators (HDS). The HDS is a

computer-based training tool designed to give commanders and their staffs realistic experience in decision making during hurricane preparations operations. The MFRHTC is particularly susceptible to tropical cyclones (TCs) and hurricanes because it is located just west of Miami near the southern tip of Florida. The MFRHTC tracks numerous TCs every year. With the MFRHTC as a backdrop, this thesis addresses four objectives: 1) use a mission engineering analysis process to evaluate and analyze the decisions and actions that the commander and staff of the MFRHTC in Hialeah must make in preparation for a hurricane and possible evacuation of the headquarters training center (HTC), 2) use the decomposition of the mission space to identify the types of information and resources necessary for these operations, 3) create a database support system (DBSS) for the development of future HDSs, and 4) create a conceptual design for the DBSS for future HDSs.

B. BACKGROUND

1. Tropical Cyclones

Tropical cyclones are one of nature's most destructive forces; therefore, individuals and communities that are in areas susceptible to TCs must take action and be prepared when TCs form. Not only are the areas located along the coastline vulnerable, inland areas can be threatened by rain, high winds, flooding, and tornadoes. From 1970–2010, the Atlantic Ocean, Caribbean, and Gulf of Mexico have seen on average 11 tropical storms per year, with six developing into hurricanes (National Weather Service 2013). The National Hurricane Center (NHC) defined a TC as a "rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has a closed low-level circulation" (National Weather Service 2013). The Saffir-Simpson Hurricane Scale defines the five categories of hurricanes. The NHC defines the categories of tropical depressions, tropical storm, hurricane, and major hurricane:

- Tropical Depression: maximum sustained wind speed of 38 mph (33 kts) or less
- Tropical Storm: maximum sustained wind speed between 39 and 73 mph (34 to 63 kts)

- Hurricane: maximum sustained wind speed greater than 74 mph (64 kts), but less than 111 mph (96 kts), categories 1 and 2 hurricanes

- Major Hurricane: maximum sustained wind speed greater than 111 mph (96 kts), categories 3, 4, and 5 hurricanes. (National Hurricane Center 2017a)

2. Hurricanes and the Marine Forces Reserve Headquarters Training Center in Hialeah, Florida

The MFRHTC facility is located in the city of Hialeah, just northwest of Miami and within Miami-Dade County, approximately 10 miles from the coast, 8 miles from the Everglades, and is 7 feet above sea-level. Figure 1 illustrates the MFRHTC's location. Because of its climate, ecology, and topography, Florida is highly susceptible to being struck by hurricanes. From 1851 to 2015, Florida has been directly hit by 114 hurricanes, including 37 major hurricanes (Blake, Landsea, and Gibney 2011). From 1994 to 2012, 34 hurricanes have hit southeast Florida, including nine major hurricanes (Miami-Dade County 2013). Major hurricane examples include Wilma and Katrina in 2005, Floyd and Irene in 1999, and the most destructive to Florida, Andrew in 1992. Hurricane Andrew reached category 4 status as it impacted Florida, killing 23 people, reaching winds speeds of 164 mph, creating a 17 ft storm surge, and causing $25.5 billion in damages (National Hurricane Center 2017b).

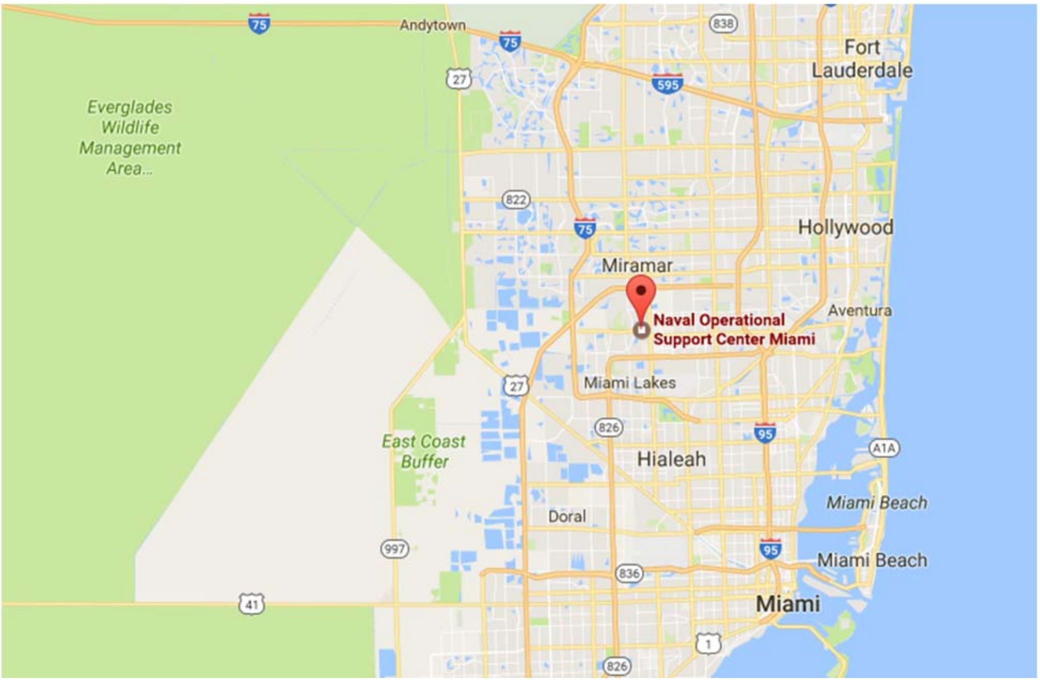

Figure 1. Marine Forces Reserve Headquarters Training Center Location (Also Known as the Naval Operational Support Center Miami). Source: Google Maps (2017).

The MFRHTC is the central location for the Marine reservists in the area and is responsible for facilitating the training and readiness of Reserve and National Guard Marines. Additionally, the facility deploys, tracks, and receives numerous United States (U.S.) military personnel in transit to and from missions throughout the world. The MFRHTC is a relatively small facility with 19 fulltime Marines, several military and government vehicles, and two buildings (Colonel Jonathon Price, Commander of the MFRHTC, personal communication, January 10, 2017). The MFRHTC maintains a hurricane preparation and evacuation plan, which is evaluated and updated yearly prior to the start of hurricane season. This plan captures how the MFRHTC prepares, the actions it must take, and the decisions it must make in preparation for a hurricane and possible evacuation. Additionally, the plan anticipates the costs, lead times of those decisions, and the timeframe in which the commander must make those decisions. The commander's decisions are largely based on the available forecasts published by the NHC and recommendations from the Miami-Dade Office of Emergency Management (MDOEM). The current hurricane preparation and evacuation plan does not spell out the exact

conditions in which the decisions should be made, nor does it account for the uncertainty in the storm forecasts, both of which could have potentially significant effects on when and how decisions are made. According to the current commander Colonel Jonathan Price, his top three priorities are: 1) safety of personnel, 2) continuity of operations, and 3) safety of facilities, which includes the HTC and the personal property of the Marines (Colonel Jonathon Price, Commander of the MFRHTC, personal communication, January 11, 2017).

3. The Hurricane Decision Simulator: Applications and Benefits

Realizing the risk to personnel, equipment, and operations that TCs and hurricanes present, in 2014 the Marine Forces Reserve Headquarters in New Orleans (MARFORRES) requested support in developing a computer-based training tool that would assist commanders and their staffs in experiencing the decision-making process through realistic simulated hurricanes. In response to this request, the Naval Postgraduate School (NPS), Dr. Eva Regnier from NPS, and Dr. Cameron MacKenzie from Iowa State University, and the Center for Educational Design, Development and Distribution (CED3) at NPS developed version one of the HDS for MARFORRES.

The three principal components of the HDS are: realistic storm simulator, a list of decisions from which the user can select, and outcomes based on the time the user selects a decision. The HDS addresses the decision-making challenges by giving users the opportunity to gain decades of valuable experience in a few hours through multiple simulations. This is significantly more experience than individuals could get through real life training and experience.

a. Tropical Cyclone Simulator

The HDS displays a realistic scenario including the TC’s track, size, and intensity, with associated forecasts and probability of winds exceeding 39, 58, and 74 mph. The TC variables, forecasts, and probability of wind speeds are updated at discrete six-hour intervals which correspond with the NHC models and updates. The HDS allows the users to make decisions based on the operational procedures of MARFORRES and simulated storm forecasts, while stepping through the simulation with new decision opportunities as

the forecasts are updated, enabling the users to train on plausible storms situations. The users receive feedback from the simulation based on the decisions they make, the time when those decisions are made, and the TC information.

b. User Decisions

The decisions offered within the HDS are the key decision that were identified that are based on discussions with the emergency operations personnel and decision makers at MARFORRES, and a review of their hurricane planning and preparations documents, including a decision support matrix which outlines six key sequential preparation decisions, with follow on actions, that the commander can make, beginning at approximately 120 hours prior to a TC's projected landfall.

The six key decisions include: (with respective time windows)

1. Deploy the advanced echelon (ADVON) party to a predetermined alternate location. (120– 96 hours before landfall)
2. Deploy liaison officers to link up and communicate with the local emergency operations center. (96–72 hours before landfall)
3. Deploy the emergency relocation staff to the alternate headquarters. (72–60 hours before landfall)
4. Activate the remain behind element (RBE) to secure the headquarters. (72–60 hours before landfall)
5. Order an evacuation or shelter in place at the headquarters. (60–48 hours before landfall)
6. Transfer command to the alternate headquarters. (48 hours before landfall) (Regnier and MacKenzie 2017)

The HDS uses these decisions and allows the user to make them throughout a simulation, without biasing the user to any decision during a simulation. The HDS allows users to see realistic simulated TCs with forecasts that evolve over time so that they can experience the unpredictability and uncertainty of decision making in hurricane preparation operations.

The simulation, designed by Regnier and MacKenzie, and developed for online delivery by CED3, starts with a TC formation in the central display, with initial forecast projection, as seen in Figure 2. At the top, the user can choose to view wind speed

probabilities of 39, 58, or 74 mph, or the TC predicted path with the error cone. On the right of the wind-speed graphics is a color-coded key that depicts the probabilities seen in the central display. On the left is a record of events where the user can access TC information, recorded decisions taken with the associated follow on actions. On the bottom left is the first key decision the user can select, which the use can only select one decision at a time. On the bottom is the current TC forecast and information. As the simulation progresses, the user is prompted with forecast updates at 6-hour intervals.

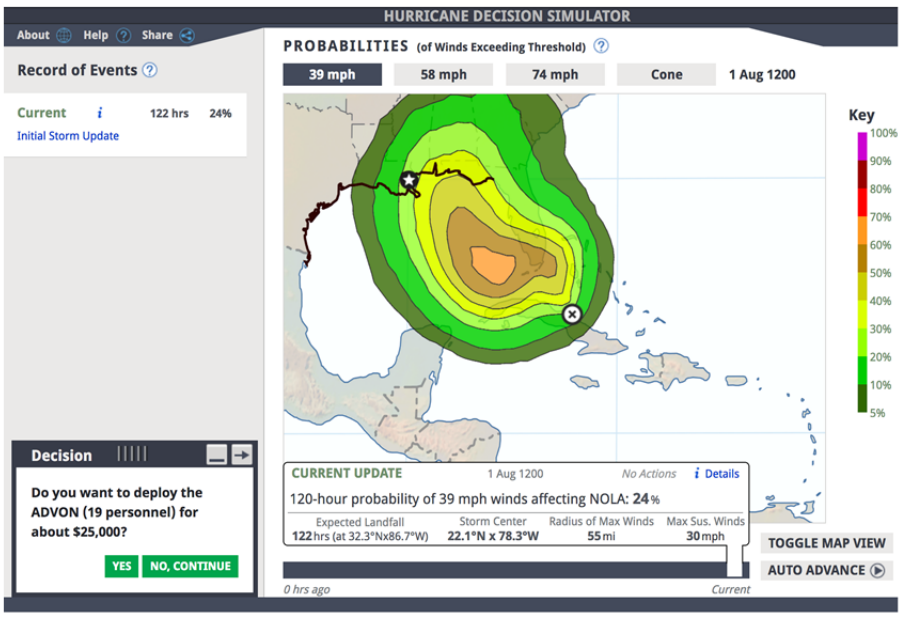

Figure 2. Simulation Start. Source: U.S. Marine Forces Reserve (2016).

The MARFORRES HDS has a specific decision logic, displayed in Figure 3. If the user decides to take a preparation action, the decision is recorded and the simulation progresses and the user is prompted for the next decision at the next forecast update. If the user choses to not take a preparation action and to continue the simulation instead, the user is offered the decision whether to take the same preparation action at the next storm forecast update. The user can create a compressed timeline by taking preparation actions in quick succession that does not align with the MARFORRES decision support matrix if the forecasts indicate that the TC grows in strength, is more likely to strike New Orleans, or the TC approaches land more quickly than expected. Additionally, due to the

uncertainty in TC track forecasts the projected time to landfall that the HDS presents does not change in six-hour time steps, but can vary by several hours. A detailed simulation example can be seen in the Appendix.

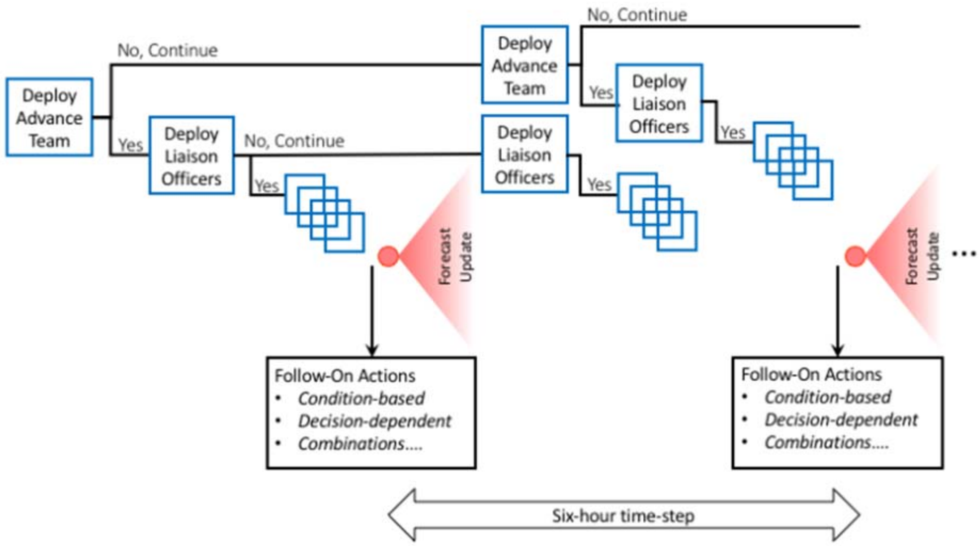

Figure 3. MARFORRES HDS Decision Logic. Source: Regnier and MacKenzie (2017).

c. *Simulation Outcome and Feedback*

The outcome of the model is based mainly on information from MARFORRES subject matter experts in emergency management, logistics, operations, and communications. The decisions made by the user during the simulation may result in disruptions in operations or monetary costs, or create difficulties in completing the hurricane preparation operations. The HDS describes the consequences of the storm impacts in general terms. For example, if no preparation actions are taken and a category 3 hurricane strikes New Orleans, the simulation feedback will display:

> MFR headquarters in New Orleans can be used for a limited time period. Key infrastructure in New Orleans is damaged because of the hurricane. Power outages cover much of New Orleans. Communications in the city are difficult, and many roadways are flooded. It may be difficult to purchase groceries and fuel. Water may also be in short supply. Many MFR personnel unable to get to work. MFR personnel are very preoccupied about the safety and well-being of their families. Some mission essential functions

> cannot be performed. The ability of MFR to continue operating at the New Orleans headquarters depends on its ability to resupply its generators and the status of the local infrastructure (such as when power is restored and the availability of water). Local authorities and homeland security officials conduct a damage assessment of the city and prioritizes who receives power first. (Regnier and MacKenzie 2017, 24)

The simulation ends after the storm has made landfall or dissipates. The user is given feedback based on the time the user made decisions, the impacts of the subsequent actions coupled with the decisions, the impacts of the state and city actions taken, and the direct storm impacts to New Orleans, such as infrastructure damage. Through the feedback, the user can gain experience not only about the decisions, actions, and costs that MARFORRES must make or pay, but the impacts of the state and city actions on the preparations. After any simulation, the user can begin to understand the effect of the timing on their decisions and how MARFORRES personnel and operations are impacted.

d. HDS Applications and Benefits

MARFORRES has used version one of the HDS for both individual training and group hurricane preparation exercises. The HDS is used by individuals who are assigned to the headquarters and have limited experience with tropical storms and hurricane preparations. The goal is to get them acquainted with making decisions in a complex environment filled with uncertainty (Regnier and MacKenzie 2017). Additionally, the HDS is used by MARFORRES in two annual group tabletop exercise. The first focuses on the implementation of the decisions and the second focuses on the making the decisions (Regnier and MacKenzie 2017). In both exercises, the participants include emergency operations personnel and key decisions makers (Marine Colonels, and Lieutenant Colonels, and their civilian equivalents) that would be involved in the real-life hurricane preparation operations. Using the HDS with these exercises has produced favorable results, and the individuals benefited and gained considerable experience they could not have gained elsewhere except through decades of real life tropical storms (Regnier and MacKenzie 2017).

The overall goal of each simulation is to help individuals and groups learn how to interpret the forecasts and their uncertainty, and then learn how to apply and use the

forecasts to make better decisions. Since one iteration of the simulation takes approximately 10 minutes, individuals can experience numerous TCs in a relatively short period of time. By progressing through multiple simulations, the user can gain valuable information, understanding, and practice making decisions in hurricane preparation operations.

Due to the success of using the HDS in these exercises, MARFORRES requested additional support in developing region or command-specific versions of the HDS in an effort to educate and help prepare their smaller commands and facilities for hurricane preparations operations. Other organizations, such as the Federal Emergency Management Agency Region 6 and the United States Army Corps of Engineers in New Orleans have shown interest in the continued development and use of the HDS (Jose Garcia, Emergency Operation Manager at MARFORRES, personal communication, December 13, 2016).

C. PROBLEM STATEMENT

The MARFORRES HDS is not suitable for use by the MFRHTC in Hialeah, Florida or any other MFRHTC other than MARFORRES in New Orleans. The HDS is a static model that cannot adapt to any environment. New Orleans is a different location than Miami and has different topographical, environmental, and weather concerns. Though both cities have emergency management offices that coordinate activities, they operate differently due to the locations and unique perspectives. The units are significantly different. MARFORRES headquarters in New Orleans is a huge headquarters with over 3000 civilians and military personnel while the MFRHTC in Hialeah is small with only a handful of full time military personnel (Colonel Jonathon Price, Commander of the MFRHTC, personal communication, January 11, 2017). The MFRHTC in Hialeah requires their own unique HDS where their unit’s decision, actions, and hurricane preparation operations can be applied so that they can gain valuable experience in hurricane decision making prior to an actual storm. In order to develop the HDS, the DBSS must be designed and created. The DBSS must contain the unique information, decision, actions, and hurricane preparation operations for the MFRHTC in Hialeah.

II. LITERATURE REVIEW

This chapter, reviews and analyzes to the current knowledge base for making decisions in hurricane preparation operations.

A. HURRICANE ORGANIZATIONS

Worldwide, there are several TC centers that study, predict, monitor, and track TCs around the world, displayed in Figure 4. These organizations aim to mitigate the loss of life and damage to property from TCs by providing forecasts to governments and people in their respective regions. This thesis will focus on Region 1, specifically the NHC located in Miami, Florida. Other organizations or sub-organization of the NHC include: National Oceanic & Atmospheric Administration, National Weather Service, National Centers for Environmental Protection, Atlantic Oceanographic & Meteorological Laboratory, the Technology and Science Branch, and the Hurricane Research Division.

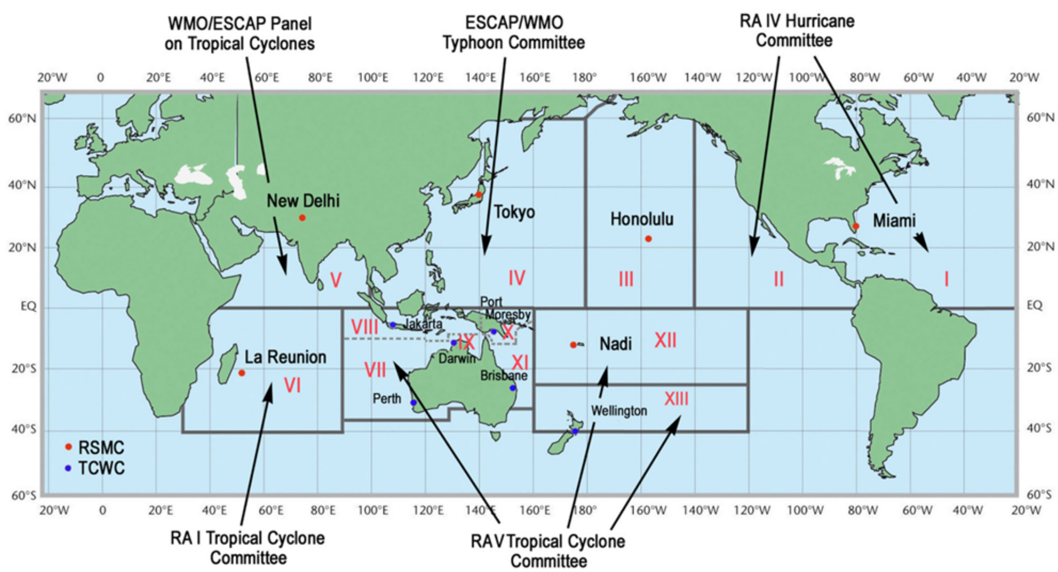

Figure 4. Worldwide TC Regions. Source: National Hurricane Center (2017c).

1. National Hurricane Center

The NHC issues real-time watches, warning, forecasts, and analysis of tropical storms in text and graphics as storms develop in the Atlantic and Eastern Pacific Oceans. These texts and graphics were used in the development of the HDS.

The NHC's Technology and Science Branch develops, tests, and integrates new and existing technologies and tools into tropical weather predictions models. The Technology and Science Branch uses several models (statistical and dynamical) that are used for forecasting and predicting TC behavior and the associated weather conditions (such as storm surge, wind, rainfall). The Technology and Science Branch assisted the Naval Research Laboratory in the development of the Automated Tropical Cyclone Forecasting System (ATCF), a computer web-based application, which integrates various information and models to automate and optimize portions of the TC forecasting process (National Hurricane Center 2017d).

The ATCF is used by TC forecasters for situational awareness and understanding, training, and research. Sampson and Schrader (2000) indicated that it allows forecasters to consolidate forecasts, generates the consensus (average) track, and lets forecasters place forecasts. It lets forecasters easily generate messages, and issue warning and advisories for areas in the TC's projected path. The system also stores past TC data for users to review and study. The system allows coordination and sharing of TC data and information between multiple agencies in a near real-time common framework, which enables decision makers across agencies to make informed decisions (Naval Research Laboratory 2010). Several pictures are displayed in Figure 5 and Figure 6 of the ATCF user interface using Hurricane Irene as an example. In the figures, the "Objective Aids" tool box allows the user to select the center of the forecasts, date, time, the specific model forecast, and then display the fields in the graphic.

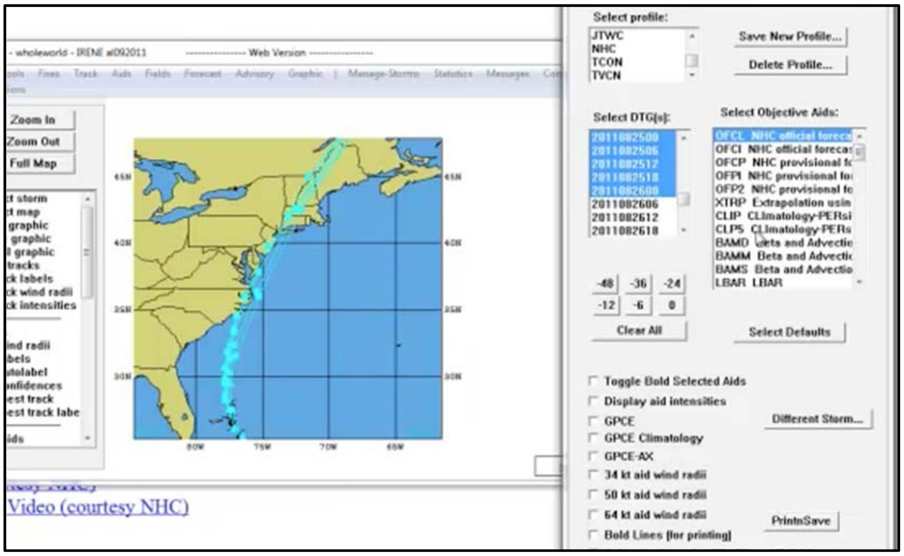

Figure 5. The ATCF User Interface of Hurricane Irene with the Official NHC Model Forecast Over a Multiple Day Period. Source: Naval Research Laboratory (2010).

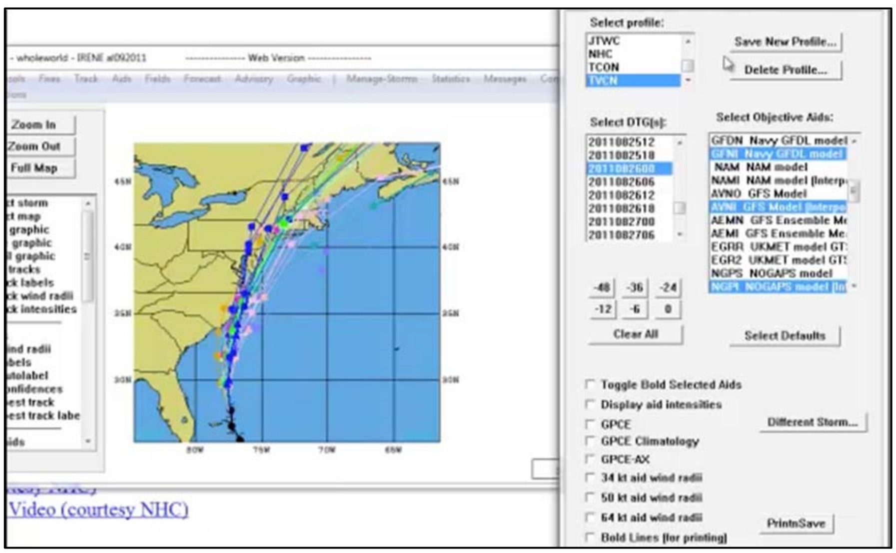

Figure 6. The ATCF User Interface of Hurricane Irene with Various Model Forecasts for a Specific Period. Source: Naval Research Laboratory (2010).

Though the ATCF is a useful automated tool, it does not replace the expertise and judgment of human forecasters in making decisions in TC preparation operations.

2. Miami-Dade County Office of Emergency Management

Miami-Dade County is located in the southeast corner of Florida and is home to the MFRHTC; therefore, it is the emergency management office relevant to this thesis. The city of Hialeah has an emergency management office but the MDOEM's actions have a bigger impact on the MFRHTC in large part because the county's evacuations substantially affect the times required for the MRFHTC to evacuate and complete other actions. The MDOEM operates much like a military tactical or joint operation center, with the exception that it is only used in the event of an emergency that threatens the entire county. The MDOEM maintains a comprehensive emergency management plan designed to address a variety of possible threats to the county, its citizens, and businesses. The essential purpose of the comprehensive emergency management plan and MDOEM is to provide a structured and coordinated system for preparedness, response, and recovery for the county. During an emergency, the MDOEM is the central hub of information, action, and news for the county. The magnitude of the event determines the scale at which the MDOEM is used. The comprehensive emergency management plan is divided into several sections: situations and assumptions, concept of operations, responsibilities, and preparedness.

Tropical cyclones are the greatest threat to the county and their activity is continuously monitored by the MDOEM. When a TC develops in the Caribbean Sea, Atlantic Ocean, or Gulf of Mexico, the MDOEM monitors the storm, its forecasted track, and intensity. As the TC develops, moves toward Florida, and increases in intensity (especially to hurricane status) the MDOEM prepares for the potential impacts. In order to help the MDOEM make decisions, they have developed six hurricane protective action decision making guides with evacuation clearance times. These guides assist the MEOEM in issuing warnings and evacuations by using the forecasted wind cone probability forecasts, wind speed, time to landfall, probability of increasing winds, probability of storm surge, impact to the evacuation zones, inland flooding hazards, and category of hurricane. Attached within the guides are the calculated clearance times to evacuate each of the evacuations zones. Figure 7 displays the evacuation zones, where the teardrop depicts the MFRHTC's location. Additionally, the MEOEM uses a public

storm-surge simulator developed by Florida International University that predicts the potential level of water at specific locations based on the category of hurricane. Graphics for each level of hurricane can be found on the National Hurricane Center website. Figure 8 displays the predicted storm surge (water level) at the MFRHTC location for a category 5 hurricane, where the teardrop depicts the MFRHTC's location. From the evacuation zone planning map and the storm surge simulations, one can see that the MFRHTC is not in any of the evacuation zones nor any of the predicted storm surge areas, but this does not mean that it will not receive any flooding. The evacuation zone maps and storm surge simulations do not account for rainfall, which accompanied with storm surge and wind could cause substantial flooding at the MFRHTC's location.

The MEOEM has gone through extensive planning and preparation for a hurricane strike. The comprehensive emergency management plan, protective action decision making guides, storm surge simulator, and established evacuation zones are all useful tools, but ultimately humans (decision makers) must always be in the loop and are responsible for mitigating the loss of life and damage in the event of a hurricane strike.

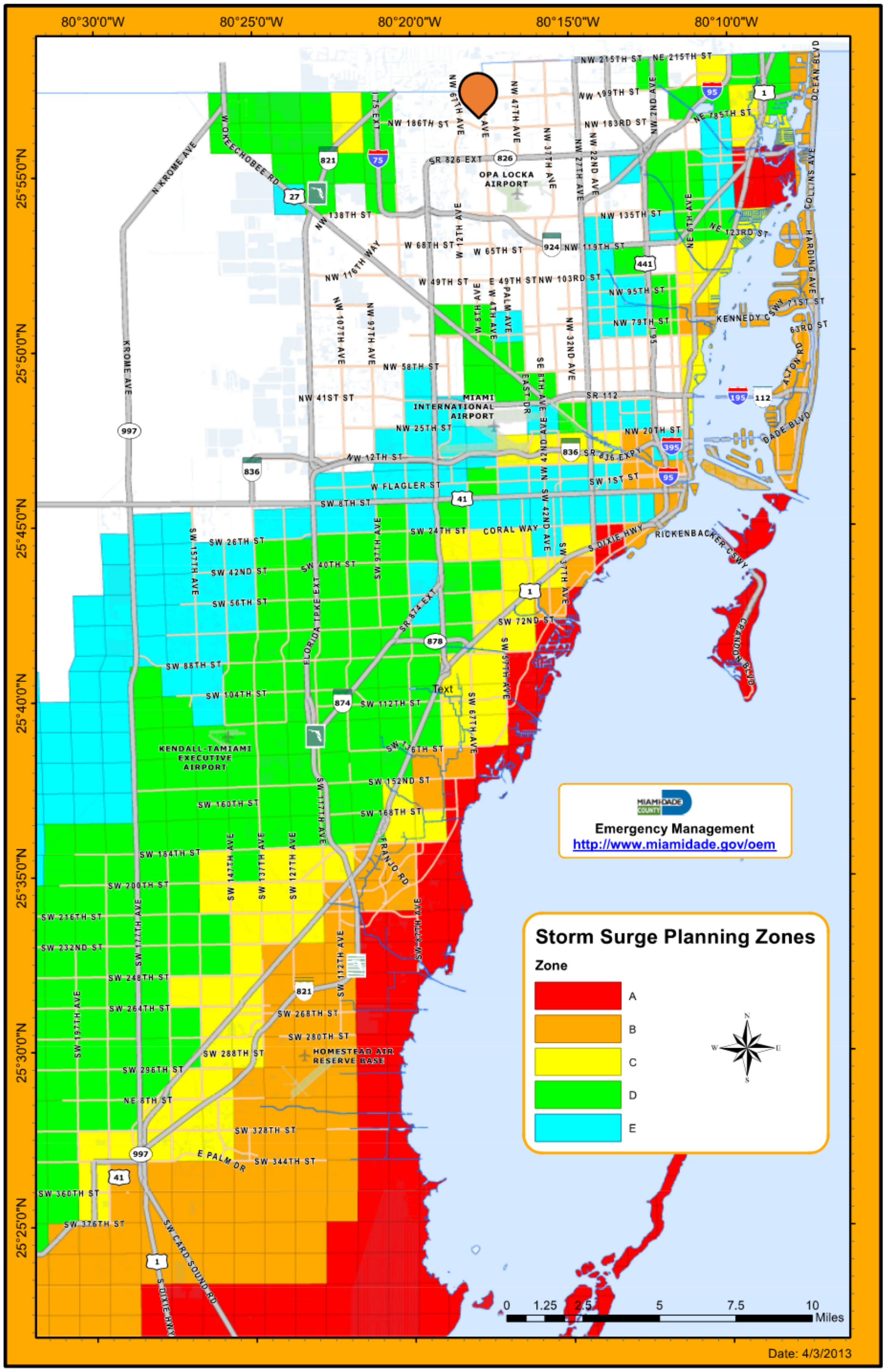

Figure 7. Storm Surge Evacuation Planning Map. Adapted from Miami-Dade County (2013).

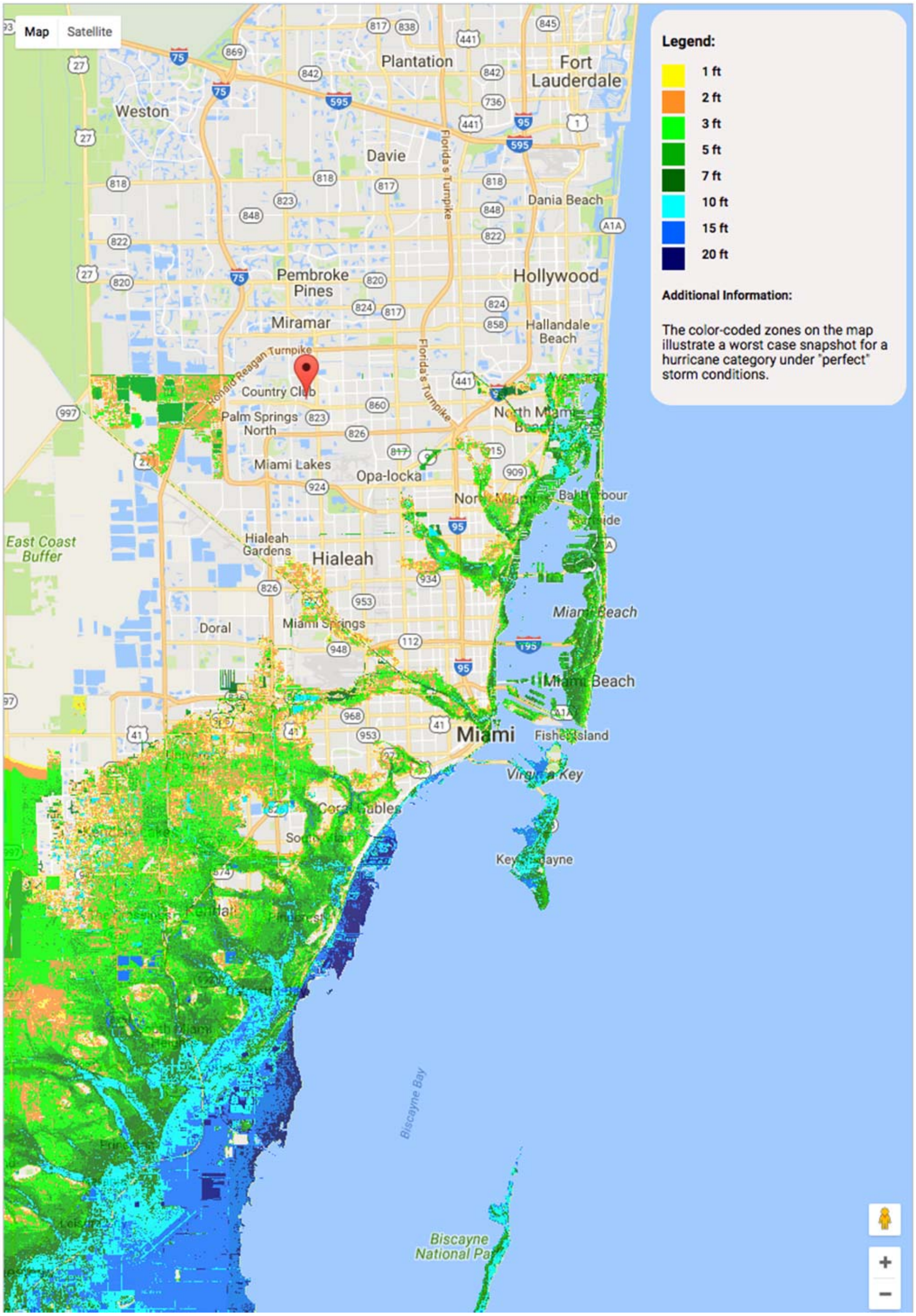

Figure 8. Storm Surge Simulator—Category 5. Source: Florida International University (2017).

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III. METHODOLOGY

This chapter describes how a system engineering (SE) framework can be applied to develop future HDSs and the methods, purpose, and type of data and information collected in this thesis. It explains how SE, the U.S. Army design methodology, and the military decision making process (MDMP) combine together to form the mission engineering (ME) analysis process. Evaluating hurricane preparation operations through a ME analysis approach shapes what the DBSS is and helps understand the information and resources required for the creation of a mission plan.

A. APPLYING A SYSTEM ENGINEERING FRAMEWORK TO DEVELOP FUTURE HDSS

1. System Engineering

The International Council of Systems Engineering, defines SE as:

> An interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. (International Council of Systems Engineering 1998)

Through SE, various disciplines and specialty groups are integrated to perform a structured system or product developmental process. This process begins with a customer needs analysis and definition of problem. It progresses through production, operation, and eventual retirement of a system. SE considers both the technical and business needs of all the stakeholders and customers with the goal of providing the customer or user with a quality product or process (International Council of Systems Engineering, 1998). Systems engineering established the process (mission plan in ME) as well as creates the product (mission in ME and the DBSS for the HDS in this thesis).

2. Systems Engineering Process

The SE process starts with a customer needs analysis and ends with an output (product or process). The SE methodology consists of seven basic steps or functions in

between, which are detailed in the International Council of Systems Engineering SE process in Figure 9. The steps in the process are not performed in sequence, rather they are performed in an iterative and parallel manner. The SE process can be applied throughout the entire process of developing the HDS. An SE approach is instrumental in creating a conceptual design for the DBSS that will be used for future HDS versions.

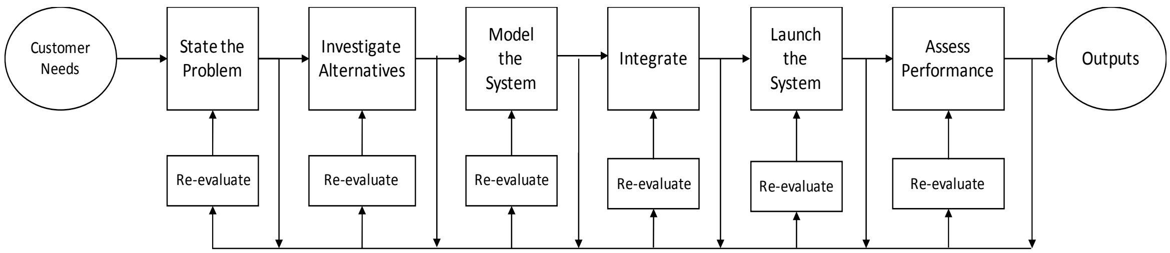


Figure 9. The International Council of Systems Engineering Systems Engineering Process. Adapted from International Council of Systems Engineering (1998).

3. Waterfall Process Model

The waterfall process model (depicted in Figure 10) is one of many process models used in SE. The process model was designed for software engineering and fits best with the design and development of the HDS. The waterfall process model is a sequential design model in which progress flows steadily downwards (like a waterfall) through the typically applied steps listed in Figure 10. The primary advantages of the waterfall model include: departmentalization and control with no overlapping steps and a well-established schedule with milestones, deadlines for each step, and an iterative feed process that enables refinement.

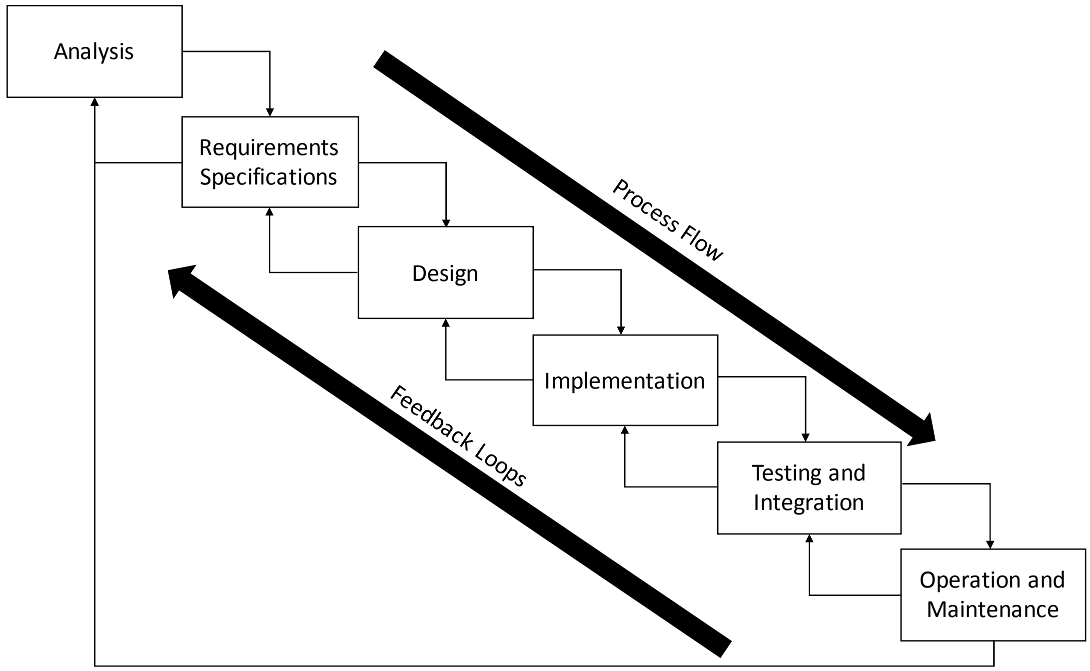


Figure 10. Waterfall Process Model. Adapted from Blanchard and Fabrycky (2011).

The MARFORRES HDS comprised one iteration of the waterfall model and the Hialeah HDS is currently in the design step of the second iteration.

4. The Product Life-Cycle of the HDS

The HDS product life-cycle (depicted in Figure 11) can be divided into four concurrent phases arranged in parallel. The acquisition phase includes: conceptual and preliminary designs, detailed design and development, production and construction. The utilization phase includes: product use, support, phase-out, and disposal. Version one of the HDS is in the utilization phase while version two is in the production and construction phase. Though all of the phases and steps in the HDS's life cycle are important, this thesis will focus on developing a conceptual design for the DBSS future HDSs so that MARFORRES can develop HDS versions for other MFRHTCs. Individual tailored HDSs will help train the commanders, staffs, and personnel at the smaller unit headquarters so they will be better equipped to make decision when threatened with TCs

and hurricanes. The tailored HDSs each require a DBSS with unique information, decisions, actions, and hurricane preparation operations to their location and unit. The conceptual design that will be detailed in Chapter V is essential to creating functional DSSs.

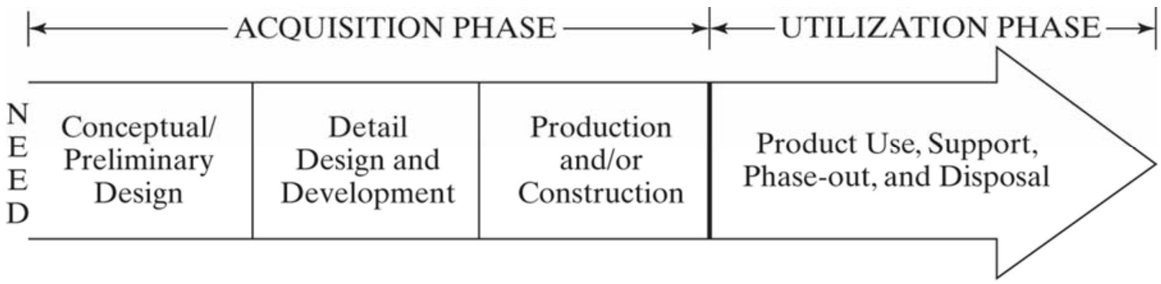


Figure 11. The Product Life-Cycle Phases. Source: Blanchard and Fabrycky (2011).

In turn, the product life cycle phases can be related to the waterfall model in Figure 10:

- customer need, conceptual and preliminary designs ↔ analysis, requirements specifications, and a little into the design step
- detailed design and development ↔ design
- production and construction ↔ implementation, testing, and integration
- products use, support, phase-out, and disposal ↔ operation and maintenance

The product life-cycle phases can be related to the MDMP in Figure 13:

- customer need ↔ step 1 (receipt of mission)
- conceptual and preliminary designs ↔ steps 2-3 (mission analysis and COA development)
- detailed design and development ↔ steps 4-6 (COA analysis, comparison, and approval)
- production and construction ↔ step 7 (orders production)
- products use, support, phase-out, and disposal ↔ OPORD execution

Understanding the customer need leads to the developing the conceptual design. Developing a conceptual design for the DBSS for future HDSs is the first step in the design and development process. A conceptual design consists of the following:

- defining the problem and needs identification
- planning and architecting the system for the needs identified
- conducting a system feasibility analysis
- defining and developing the system's operational requirements
- defining a concept for the system's maintenance and support requirements
- identifying, establishing, and prioritizing technical performance measures
- conducting a functional analysis and allocating requirements to components and systems
- conducting a system trade-off analysis
- conducting a conceptual design review and implementing changes if needed (Blanchard and Fabrycky 2011)

B. MISSION ENGINEERING AND THE MILITARY DECISION MAKING PROCESS

1. Mission Engineering

Mission engineering is defined by the Office of the Deputy Assistant Secretary of Defense for Systems Engineering as the "deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects" (Gold 2016, 3). Mission engineering will be used to examine how the HDS and DBSS can be used by the MFRHTC in Hialeah. It will define the mission of the HDS, determine the information and resources requirements of the DBSS, and help develop a plan to integrate the HDS into the MFRHTC capabilities. The ME process (displayed in Figure 12) is circular and requires all three parts to work in conjunction with each other to perform successfully. It starts with systems acquisition, transitions to mission, system of system (SoS) architecture, and engineering, then moves to operations, which returns to systems acquisition.

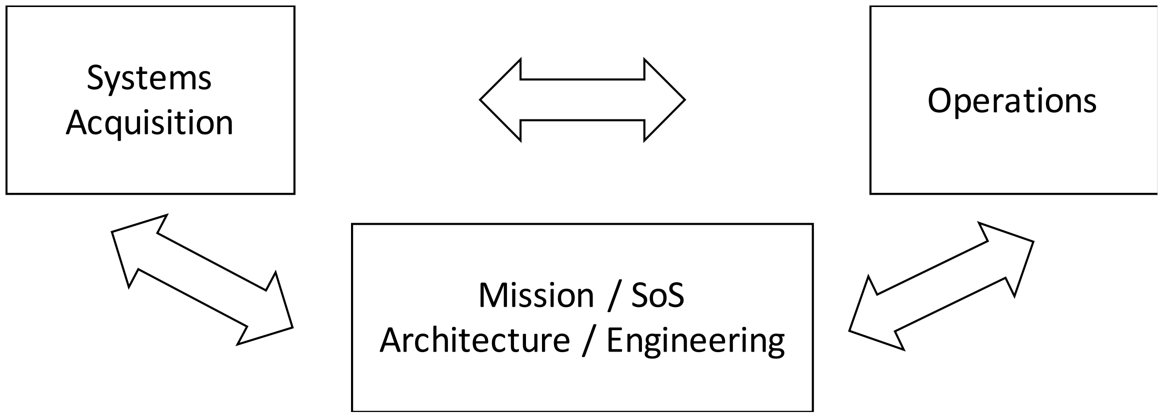


Figure 12. Mission Engineering Process. Adapted from Gold (2016).

In ME, the mission and mission plan are the "system." The mission consists of the "who," "what," "when," "where," and "why," and the mission plan is the "how." The HDS used the waterfall process model (discussed earlier in this chapter) as a means to accomplish the mission. The waterfall process model is the link (double arrows) between the mission, SoS architecture, and engineering and operations in ME. Mission engineering explores and addresses the tradeoffs at multiple levels between individual systems, components, and the data exchanges among the systems and components over the entire mission and system (Gold 2016). Throughout the ME process, SE is applied to support the operational mission objectives. Mission engineering is instituted in the design and development of the HDS in the following ways:

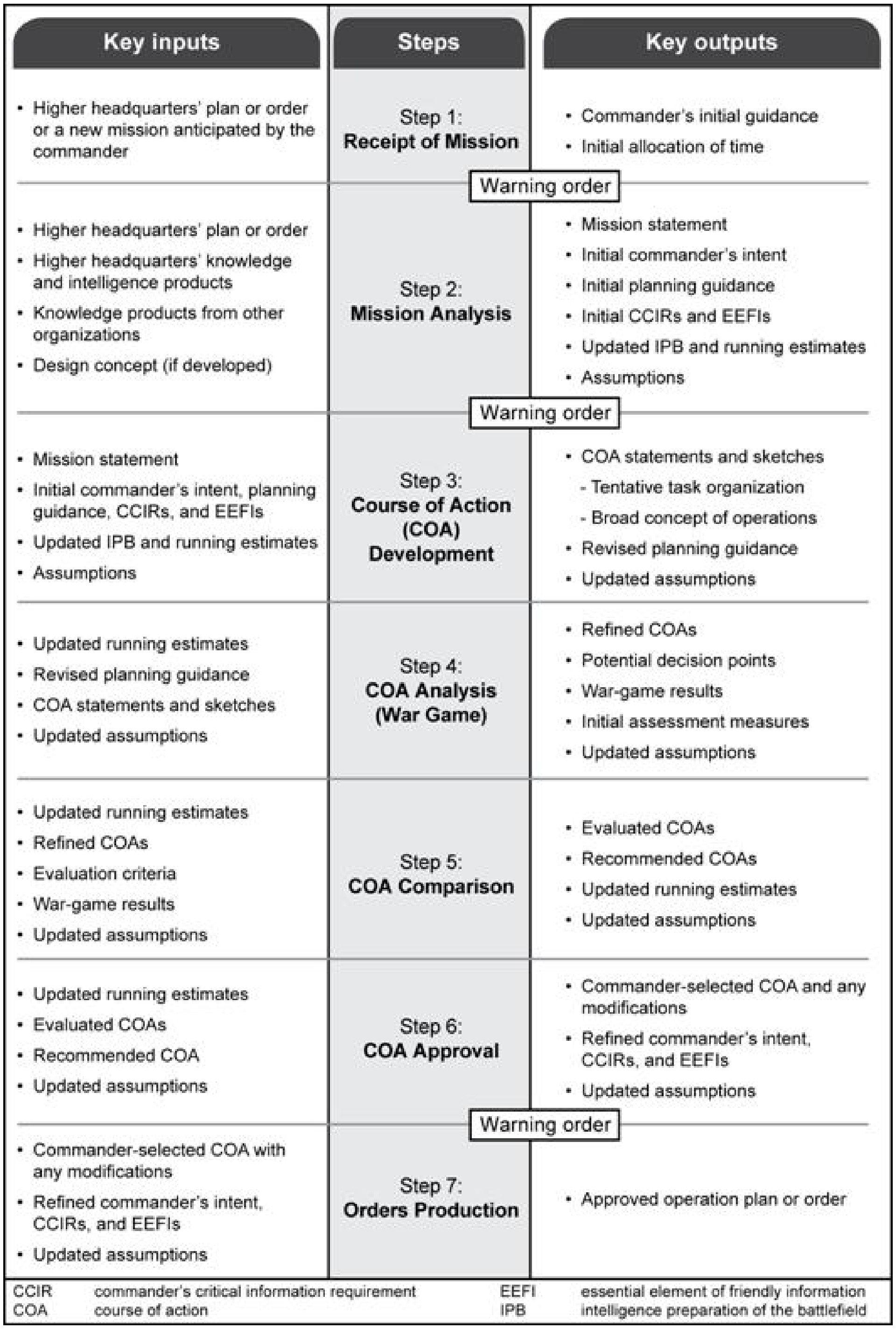
- enables the mission outcomes to be defined to identify and frame the problem
- establishes mission success factors and performance requirements for individual components and systems
- aligns the mission, current state, and desired end state with all of the stakeholders
- creates a single framework to analyze the mission
- develops assessment frameworks which can be used to measure progress through the end-to-end mission execution and completion (includes system integration with other system, test and evaluation, and exploring mission threads) (Gold 2016)

2. The Military Decision-Making Process

The Military Decision-Making Process (MDMP) is defined by the Center for Army Lessons Learned as:

> An iterative planning methodology that integrates the activities of the commander, staff, subordinate headquarters, and other partners to understand the situation and mission, develop and compare courses of action (COAs), decide on a COA that best accomplishes the mission, and produce an operation plan or order for execution. The MDMP helps leaders apply thoroughness, clarity, sound judgment, logic, and professional knowledge to understand situations, develop options to solve problems, and reach decisions. The MDMP is a process that helps commanders, staffs, and others think critically and creatively while planning. (Center of Army Lessons Learned 2015, 7)

The MDMP process helps all stakeholders by laying out a framework to solve problems and plan complex operations. Figure 13 depicts the MDMP process, with the steps listed in the center, and each step's inputs on the left and outputs on the right.



Key inputs	Steps	Key outputs
• Higher headquarters' plan or order or a new mission anticipated by the commander	Step 1: **Receipt of Mission**	• Commander's initial guidance • Initial allocation of time
	Warning order	
• Higher headquarters' plan or order • Higher headquarters' knowledge and intelligence products • Knowledge products from other organizations • Design concept (if developed)	Step 2: **Mission Analysis**	• Mission statement • Initial commander's intent • Initial planning guidance • Initial CCIRs and EEFIs • Updated IPB and running estimates • Assumptions
	Warning order	
• Mission statement • Initial commander's intent, planning guidance, CCIRs, and EEFIs • Updated IPB and running estimates • Assumptions	Step 3: **Course of Action (COA) Development**	• COA statements and sketches - Tentative task organization - Broad concept of operations • Revised planning guidance • Updated assumptions
• Updated running estimates • Revised planning guidance • COA statements and sketches • Updated assumptions	Step 4: **COA Analysis (War Game)**	• Refined COAs • Potential decision points • War-game results • Initial assessment measures • Updated assumptions
• Updated running estimates • Refined COAs • Evaluation criteria • War-game results • Updated assumptions	Step 5: **COA Comparison**	• Evaluated COAs • Recommended COAs • Updated running estimates • Updated assumptions
• Updated running estimates • Evaluated COAs • Recommended COA • Updated assumptions	Step 6: **COA Approval**	• Commander-selected COA and any modifications • Refined commander's intent, CCIRs, and EEFIs • Updated assumptions
	Warning order	
• Commander-selected COA with any modifications • Refined commander's intent, CCIRs, and EEFIs • Updated assumptions	Step 7: **Orders Production**	• Approved operation plan or order

CCIR commander's critical information requirement
COA course of action
EEFI essential element of friendly information
IPB intelligence preparation of the battlefield

Figure 13. Military Decision-Making Process. Source: Center of Army Lessons Learned (2015).

The waterfall process model, Figure 10, relates to both ME and the MDMP. In ME, Figure 12, it is the double arrow that links mission, system of systems, architecture, and engineering to operations. In the MDMP, Figure 13, the waterfall process model is associated with all the steps in the process:

- analysis and requirements specifications ↔ steps 1-2 (receipt of mission and mission analysis)
- design ↔ steps 3-6 (Course of Action (COA) development, analysis, comparison, and approval)
- implementation, testing and integration, operation and maintenance ↔ step 7 (orders production and operations)

During mission analysis step, the U.S. Army design methodology (depicted in Figure 14) is applied. The methodology allows individuals and groups to apply "critical and creative thinking to assist in understanding, visualizing, and describing" a problem and the possible solutions or approaches to solving the problem (Center of Army Lessons Learned 2015, 3). The methodology is especially useful in aiding conceptual design, initial planning, and outlines further detailed planning, which is normally connected with the MDMP in producing an operations order (OPORD). While developing future HDSs for new locations, the methodology can be applied to the conceptual and preliminary designs. The methodology begins by first framing an operational environment by describing the current state and the desired end state. It continues by framing the problem and describing the obstacles that stand in front of the desired end state. It continues by developing an operational approach to solve the problem and describing the decision and actions that could resolve the problem. This leads to the development of a plan, in which the MDMP is used.

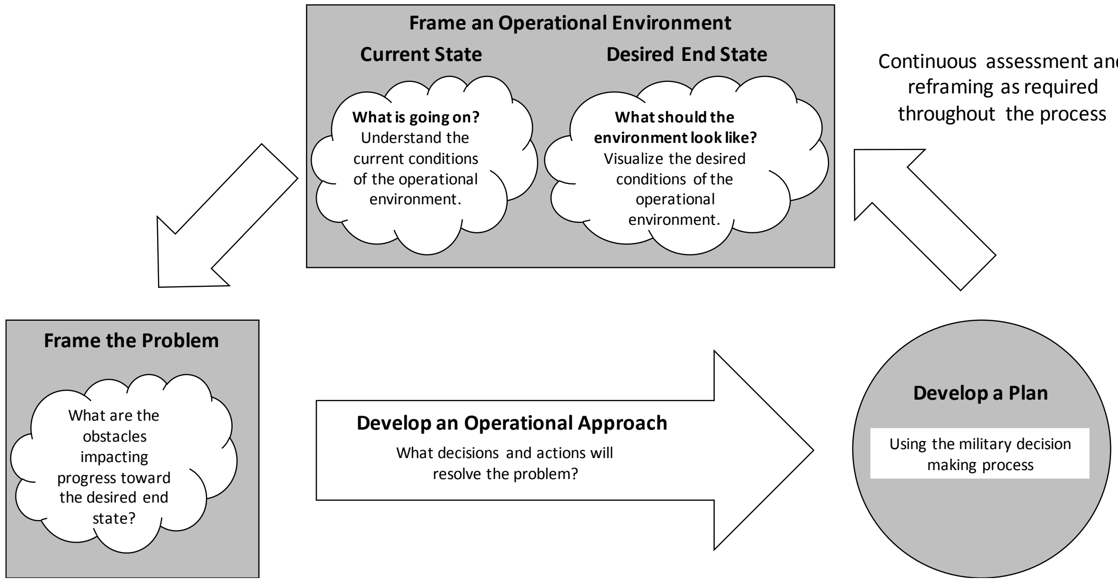


Figure 14. U.S. Army Design Methodology. Adapted from Center of Army Lessons Learned (2015).

The key outputs listed in the mission analysis step of the MDMP, Figure 13, and the results of the U.S. Army design methodology, Figure 14, are the same: a problem or mission statement, understanding of and the initial commander's intent and planning guidance, and an operational approach (updated initial preparation of the battlefield and running estimates) that serve as the links between conceptual and detail planning (COA development). At the conclusion of the MDMP an OPORD is produced, which outlines the specifics on how and why the mission will be accomplished. The OPORD is the mission plan with the HDS as the mission. Though this thesis will not produce an OPORD, the thought process behind the OPORD, MDMP, and U.S. Army design methodology must be considered because the customer is a military unit and practices the MDMP. The MDMP is the mission, SoS architecture, and engineering box in ME, as seen in Figure 12. The OPORD is the mission plan, which is executed in the operations box in ME in Figure 12.

C. DATA COLLECTION

This thesis uses two primary data resources and two case studies. The two data resources are: MARFORRES in New Orleans and the MFRHTC in Hialeah, Florida. The

case studies include the MARFORRES HDS (version one) and the Hialeah HDS (version two).

1. MARFORRES Operations and Decision Making Processes

MARFORRES is the U.S. Marine Corps Forces Reserve Headquarters in New Orleans which commands all U.S. Marine Reserve forces. MARFORRES is responsible for augmenting, reinforcing, and providing operational tempo relief to the active Marine forces in times of war, national emergencies, contingency operations, and peacetime (MARFORRES Commander 2016). MARFORRES must manage operations and personnel on missions throughout the county and in various parts of the world and cannot afford to shut down operations or lose contact with its subordinate units or personnel. Therefore, it is important for MARFORRES to track and monitor TCs that have the potential to effect operations and possibly force an evacuation. Data and information were collected during a site visit to MARFORRES from 12–14 December, 2016 when several meetings were conducted with the staff. It was essential to visit MARFORRES before visiting the MFRHTC in Hialeah to get an understanding of why the HDS was created, how the HDS is used, and figure out the future project scope and vision. During the site visit, data and information were collected to:

- understand why the HDS was created and how MARFORRES uses it
- gain insight into how MARFORRES helps MFRHTC in Hialeah
- figure out how the emergency operations center at MARFORRES deals with TCs
- determine the reporting requirements for the MFRHTC in Hialeah during a TC; and
- determine the HDS version 2 (for Hialeah) project scope and timeline.

2. MFRHTC Operations and Decision Making Processes

The MFRHTC is a local command headquarters for Marine Corps Forces Reserve in Florida. The headquarters is responsible for coordinating and managing the training, support, facility usage, and deployments of Marine Reserve forces assigned to it. The

MFRHTC has individuals deployed to various parts of the world and cannot afford to shut down operations or lose contact with their deployed personnel, and therefore must track and monitor TCs that have the potential to affect operations and possibly force an evacuation. Visiting the MFRHTC in Hialeah was important to get an understanding of the unit, its operations, facilities, and personnel. Data and information was collected during a visit from 10–12 January, 2017 where several meetings were conducted with the unit's staff and commander. During the site visit data and information were collected to:

- understand the current TC preparation procedures and operations
- learn how the unit tracks and monitors TCs
- determine the decisions and actions the MFRHTC must take in preparation for a TC, their costs, and how they relate to the HDS
- determine how the unit will use the HDS; and
- define the reporting requirements for the MFRHTC in Hialeah during a TC.

3. Versions One and Two of HDS

This thesis uses the MARFORRES HDS as an exploratory and descriptive case study. Exploratory case studies are used to present data, information, and descriptions of an event, project, or investigation. Descriptive case studies present data and information on an event, project, or research so that new data and information can be compared to pre-existing theory, data, and information. The Hialeah HDS is used as an exploratory case study.

When evaluating both the MARFORRES and Hialeah HDSs, this author seeks to understand the data and information: why it was created, how it was constructed, how it will it be used, how it will operate, and how each decision will be made or accomplished. Additionally, the evaluation will seek to discover any improvements or changes that would benefit future HDS versions. To accomplish this, a functional analysis approach using ICOM (inputs, controls and constraints, outputs, and mechanisms) charts, detailed in Figure 15, will be used. During this approach, both the HDS as a whole and key decisions will be evaluated separately.

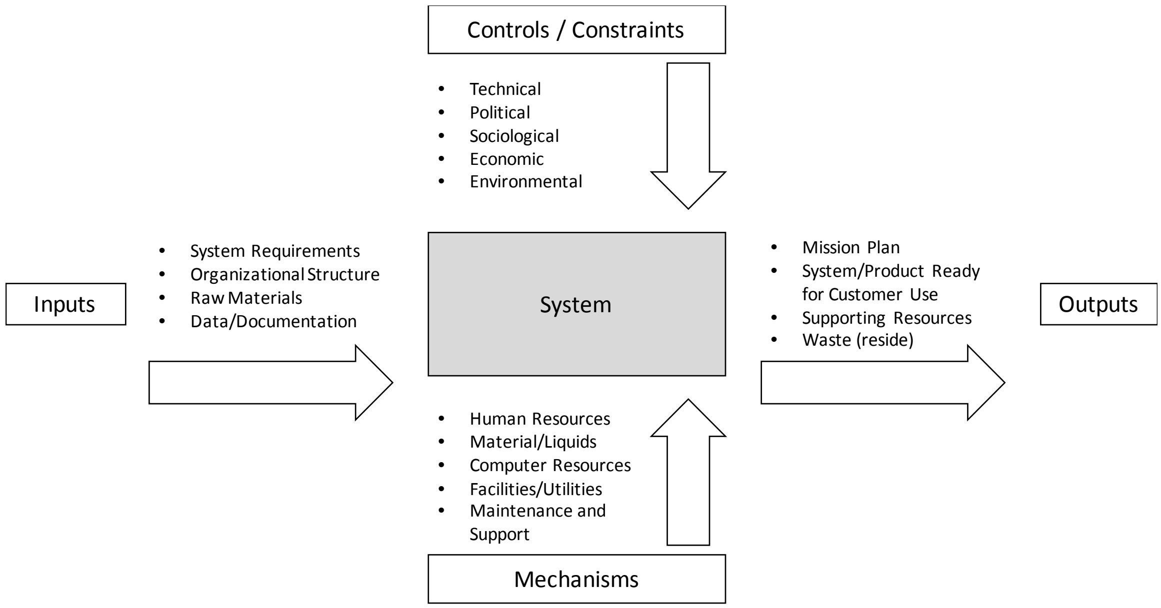


Figure 15. ICOM Chart for a Functional Analysis Process. Adapted from Blanchard and Fabrycky (2011).

The functional analysis will be used to breakdown the HDS into its components and functions. The functional analysis is a process where system requirements are translated in design criteria and then the resources required are identified for system operation and support. This process includes breaking the system level requirements down in sub-system requirements and further down as far as the hierarchical structure is required to identify the input design criteria (Blanchard and Fabrycky 2011). Breaking down the HDS in a functional hierarchy helps define the bases for functional analysis and displays the system architecture. Though this is useful in breaking the systems into smaller more manageable parts it lacks the ability to indicate the flow of functions and sub-functions in time and space. A functional flow block diagram (FFBD) satisfies this limitation and provides an understanding of the overall operational process in a logical, sequential order.

This chapter discussed the methodology of how this thesis was conducted. It defined systems engineering, the systems engineering process, and how they will be used to evaluate the HDS. It defined how ME will be used to examine what the HDS requires. It described the waterfall process model and how it related to the HDS, mission

engineering, and the military decision making process. It described the HDS product life-cycle phases and how they fit into the waterfall model and the military decision making process. It described mission engineering, the military decision-making process, the army design methodology, how they fit together into each other and the HDS, and how they are mutually supportive of one another. It described how a system engineering framework can be applied to develop a DBSS for future versions of the HDS. It summarized the data collection methods and how a functional analysis approach will be used to evaluate the HDS as the system and the key decisions. Lastly, it detailed the steps to create a conceptual design for a database support system for future HDSs. The following chapter will discuss the results of the thesis research detailed in this chapter.

IV. DATA ANALYSIS AND RESULTS

This chapter relates how the methodologies described in Chapter III are used to examine the problem. It also details the data and results. It describes how version two of the HDS can be decomposed into its components, how the components fit together and interact with each other, and the differences between the version one and two of HDS. It identifies the type of information and resources necessary for hurricane preparation operations and the key decisions that the commander can make for the MFRHTC in Hialeah. It describes how SE, ME, the MDMP are applied and used to analyze the decision-making process.

A. DECOMPOSITION OF THE HDS AND DBSS

1. Applying the SE Process and U.S. Army Design Methodology to the HDSs

In order to transform from a static database (version one of the HDS) to a dynamic database (version two of the HDS), it is important to understand the differences between the two versions, what the components of the HDS are, how they fit together and interact with each other, and to identify the information that the HDS requires. To do this, the SE process, concepts, and the U.S. Army design methodology will be used, all described in Chapter III.

In the SE process, the problem must first be stated. In the U.S. design methodology, the operational environment must be framed, with both current and desired end states identified. This can best be done by describing the differences between version one and two of the HDSs. Version one of the HDS was specific to MARFORRES in New Orleans. In version one, the information required to construct the HDS and DBSS was hard coded into the programming code and no spreadsheet existed. Because version one of the HDS was successful and accomplished its objectives, MARFORRES requested that additional HDSs be developed for their reserve training facilities located along the Gulf of Mexico, Caribbean Sea, and South Atlantic coast. Version one of the HDS was designed specifically for MARFORRES and the New Orleans area and was not designed

to be adaptable to different locations; therefore, it had to be redesigned. This was primarily due to the information collected being hard coded into the programming, which would have required significant time and effort to input new information into the code line by line. The HDS needed a way to transform from its current version into a version that would enable it to be adapted to new locations.

The solution was to develop a DBSS that would store the information in which the programming code would reference for the data when needed. This would require rewriting the programming code and developing a storage mechanism for the information. To make it easier to develop version two of the HDS, spreadsheets were created to allow information to be changed quickly without having to change the programming code. Figure 16 illustrates the components of version two of the HDS (end state). The arrows represent the flow of information and the circles represent interaction points between different components. The circles represent interaction points where the information from the user interface, programming code, user inputs, and DBSS (spreadsheets) interact. The current state of the HDS is illustrated in Figure 16 minus the spreadsheets.

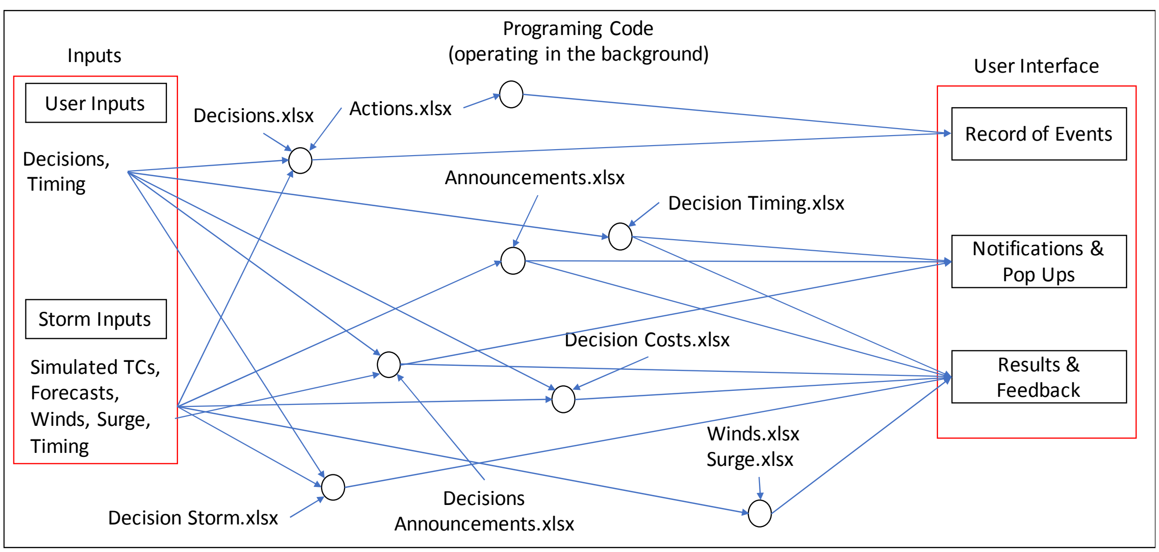


Figure 16. Schematic of the Current State of the HDS and Its Components

Version two of the HDS has four primary components: user interface, programming code, simulated TCs, and the DBSS. The user interface is what the user sees on the screen and interacts with. It was described in Chapter I, Section B.1.3, and is displayed in Figure 2 and the Appendix. For version one, Regnier and MacKenzie designed the simulation and built it in Matlab. CED3 designed the online user interface, built it in Java, pulling from data files generated by running the Matlab code repeatedly to implement the decision logic. For version two, CED3 coded the logic shown in Figure 16 directly so that the information contained in the easily understood spreadsheets can be turned into a fully functional simulator. The user interface is very similar in version two.

The simulated TCs consist of storm data that is presented to the user as updated TC forecasts, surge data, winds data, and the time associated with each. Each version of the HDS will have a set of TCs that were designed to represent plausible TCs for the location. The DBSS is primarily composed of nine spreadsheets that contain the information collected from the unit.

Next in the SE process is investigating alternatives and modeling the system. In the U.S. Army design methodology, this is developing an operational approach and determining what will resolve the problem. Two alternatives were analyzed: the current design of hard coding the information into the programming or the creating of nine spreadsheets into a DBSS and shifting to a Java only programming language. The spreadsheets were selected because they allowed for an easier transition of information between versions.

Integration is the next step in the SE process and developing a plan in the U.S. Army design methodology. This is the task that links the mission, SoS, architecture, and engineering block in ME to operations. Additionally, it is the COA development, analysis, comparison, and approval in the MDMP. Here, the tasks and steps required to develop the new DBSS for version two of the HDS were identified and the development team began work to complete them in the specified time. During this step, the information that the DBSS requires to take actions and make decision were determined and site visits to both MARFORRES and the HTC in Hialeah were conducted to gather

this information. This step is currently underway and the DBSS is being developed and integrated into the HDS.

The next steps in both processes are to launch the system, assess performance, and re-evaluate. These steps are set for the HDS version two launched in late fiscal year 2017 as the components of the HDS are finished, integrated, the system is tested, and packaged for release to the customer.

2. Information Requirements of the DBSS

The DBSS consists of nine spreadsheets. These spreadsheets include: decisions, actions, decision timing, decision costs, winds, surge, decision storm, decision announcements, and announcements. The spreadsheets are displayed in the supplemental material. Systems engineering and the MDMP were used to determine, collect, refine, and verify what information the spreadsheet required.

The decisions spreadsheet contains the key decisions that the user is prompted to make in the HDS. When the user selects a decision, the time is recorded and information is sent to five interaction points. Depending on the time the user makes the decision and the position of the TC, announcements and popups may be triggered. The key decisions are detailed in the following section of this chapter.

The actions spreadsheet contains all the actions the MFRHTC must complete when a decision is made. The time and actions are recorded in the record of events and displayed in the feedback at the end of the simulation.

The decision timing spreadsheet specifies the conditions, announcement, and results in the event a decision is made too soon after an earlier decision. If a decision is made and the specified time has not elapsed, a pop up is triggered letting the user know the results of the decision at that time. The events are listed in the feedback at the end of the simulation.

The decision costs spreadsheet details the fixed and variable cost of making each decision. Fixed costs are a one-time cost while variable costs are dependent on the wind speed and surge, which affect the duration of some activities such as an evacuation.

The winds and surge spreadsheets specify the wind and surge thresholds with their associated decisions the MDOEM would make and other consequences. If the threshold is reached, the event is listed in the feedback at the end of the simulation.

The decision announcements spreadsheet describes the announcements that pop as a result of the time when the user selects decisions in relation to announcements. For example, these describe any conflicts with local state, county, and MDOEM operations.

The decision storm spreadsheet describes the consequences of the time the user makes decisions in relation to the surge and winds conditions at the time. The events are listed in the feedback at the end of the simulation.

The announcements spreadsheet details announcements that pop up if the TC meets specified conditions based on wind cone probability, probability of wind speed, probability of surge level, and the expected TC time to landfall. If the specific condition is met, the time is recorded in the record of events, a pop up event is displayed and then is listed in the feedback at the end of the simulation. For example, announcements may describe actions by the MDOEM, or TC events like hurricane-force winds in Miami.

3. Function and Component Decomposition of the HDS Leading to the DBSS Conceptual Design

Figure 17 illustrates the functional hierarchy of the HDS. The functional hierarchy displays the HDS's functional architecture, defining the "whats" that the HDS must do and organized the functions into sub-systems in a top-down, highest to lowest logical order. The HDS functional hierarchy is illustrated to point to the location specific information storage system, or DBSS (the highlighted section in the red box). This system is required to enable to HDS to transform so that it can be tailored to new locations. A functional hierarchy is defined for the DBSS in Chapter V.

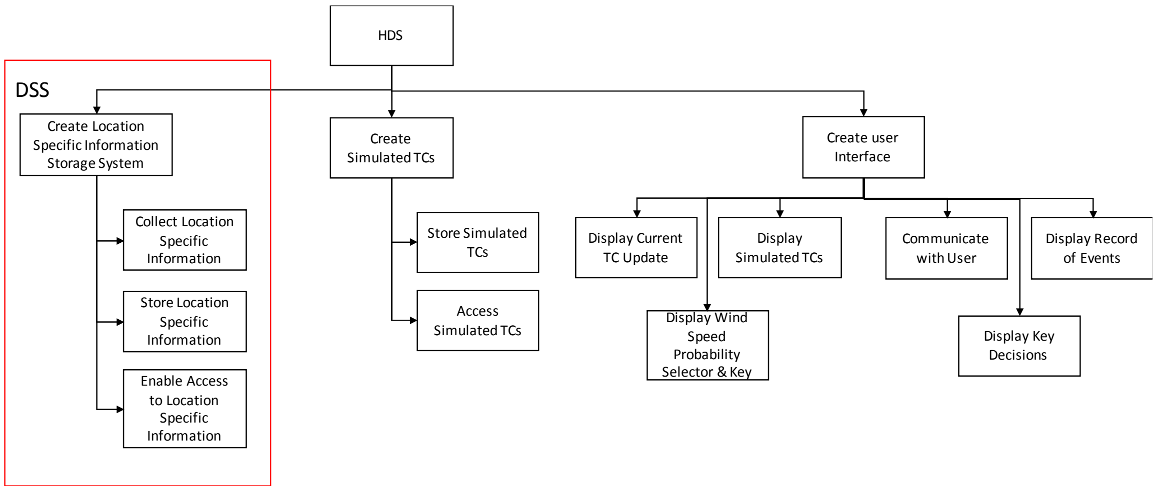


Figure 17. Functional Hierarchy of the HDS

Figure 18 illustrates a FFBD for creating a HDS. In the design and create the HDS components steps (the highlighted section in the red box) the DBSS is identified, detailed, and constructed. An FFBD for creating the DBSS is defined in Chapter V.

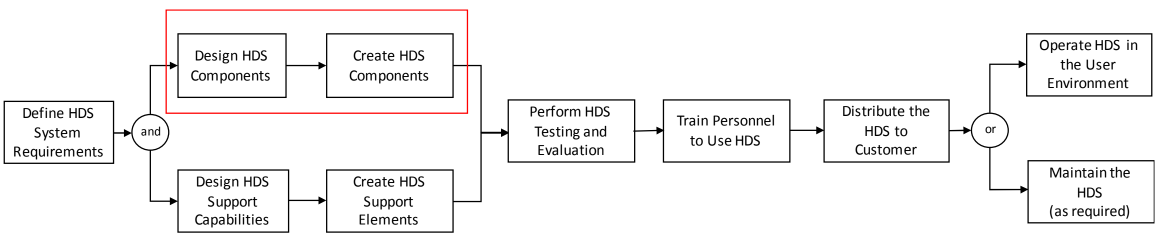


Figure 18. FFBD for Creating an HDS

Figure 19 illustrates a physical block diagram of the HDS components. In the figure the components of the HDS can be seen, where the DBSS is highlighted in the red box. Chapter V details a physical flow block diagram of the DBSS components.

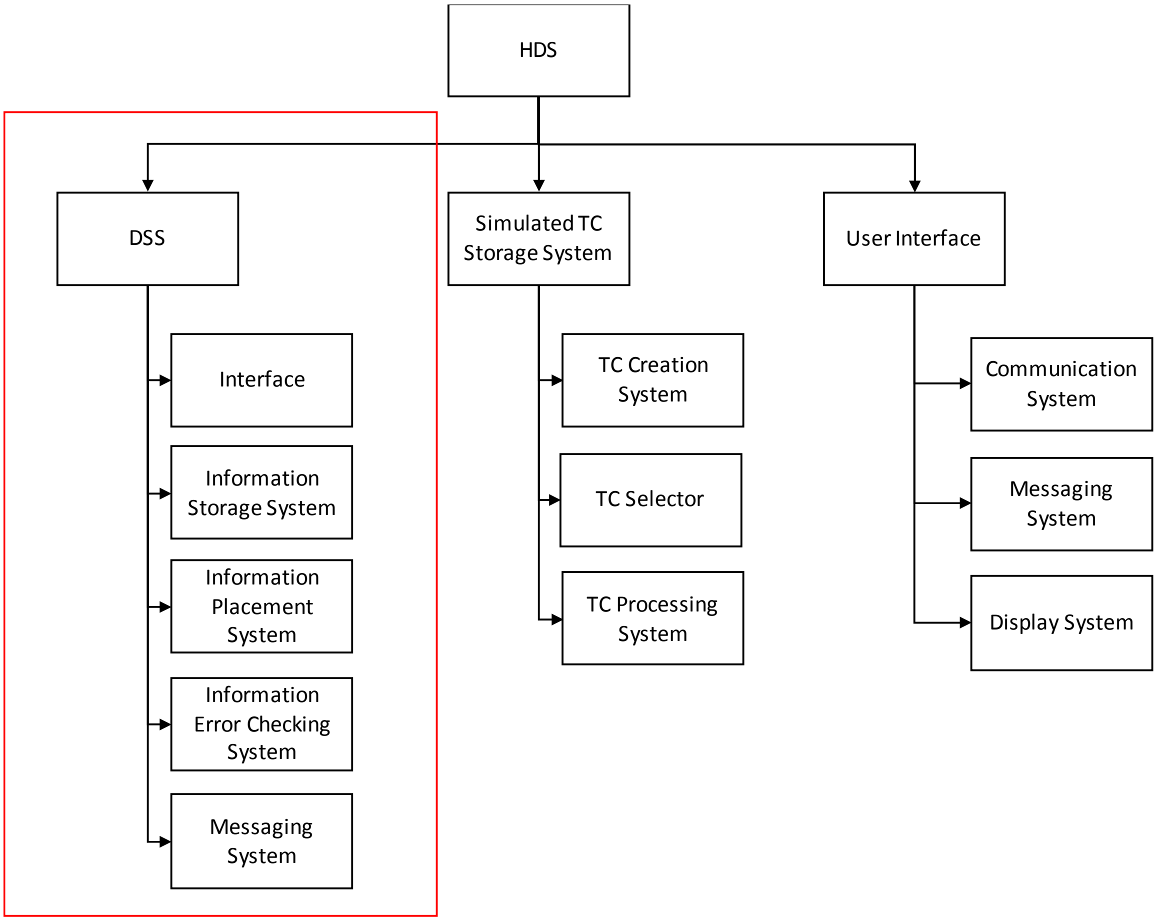


Figure 19. Physical Block Diagram of the HDS

B. ANALYSIS OF THE KEY DECISIONS AND LOGIC OF THE HDS

1. Key Decisions and Functional ICOM Analysis

The decisions offered within the Hialeah HDS are based on how the staff and commander of the MFRHTC in Hialeah constructed their process for dealing with hurricane planning and preparations. During this process, they identified seven key decisions with associated actions for each section that they are required to complete. The decisions begin approximately 120 hours prior to a TCs projected time to landfall. Additionally, the staff broke hurricane preparations operations into four phases. The phases (with respective time windows) and decisions include:

Phase 1: Pre-preparation Readiness (120 hours +)

Phase 2: ADVON Preparation (120 – 72 hours)

Decision 1: Prepare the ADVON party

Phase 3: Storm Proofing and ADVON / RBE Deployment (96 – 24 hours)

Decision 2: Storm proof the HTC and personal property

Decision 3A: Deploy the ADVON party to the alternate command and control location and authorize a voluntary evacuation

Decision 3B: Prepare and standup the RBE

Phase 4: Evacuation / Shelter in Place (24 – 0 hours)

Decision 4A: Secure the HTC and issue a mandatory evacuation order

Decision 4B: Shelter in place

Decision 5: Transfer command and control to the alternate headquarters

During discussions with the staff and commander of the MFRHTC in Hialeah decisions 2, 3A, and 3B could be made in any order. The ability to make these decisions in any order would have required a significant re-design of the current HDS programming and additional time to complete, therefore the order previously illustrated was established.

Before analyzing each decision through a functional analysis ICOM approach the entire system must be analyzed. Figure 20 displays the approach of how the inputs are transformed into the outputs. The controls and constraints guide the inputs while the mechanisms change the inputs.

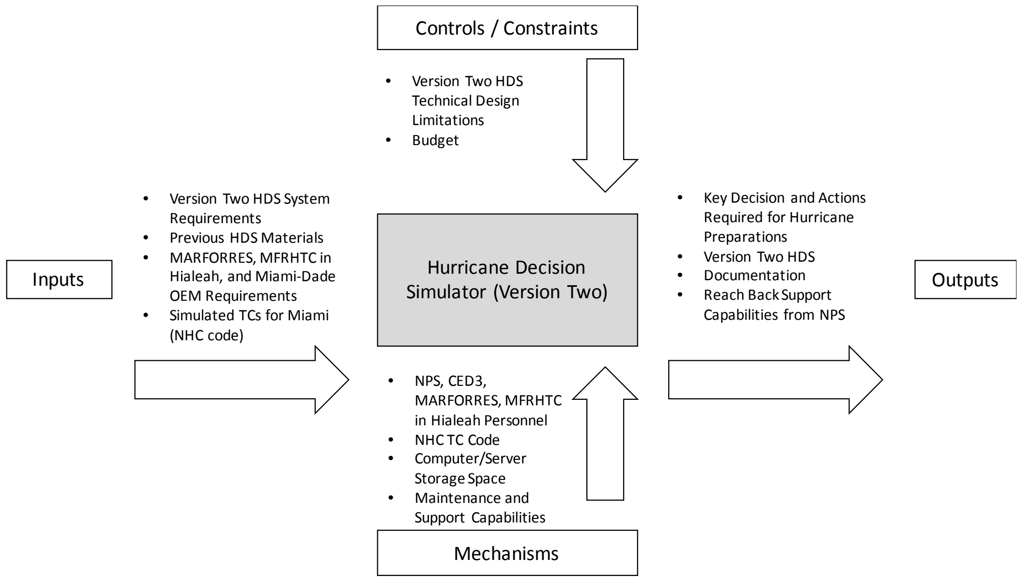


Figure 20. Functional ICOM Analysis for Version Two of the HDS

After determining what the key decisions are and analyzing the entire system though a functional analysis ICOM approach, the decisions can be analyzed individually through the same approach. Figure 21 illustrates an ICOM chart decision one, and Table 4 documents the whole ICOM analysis process for each decision.

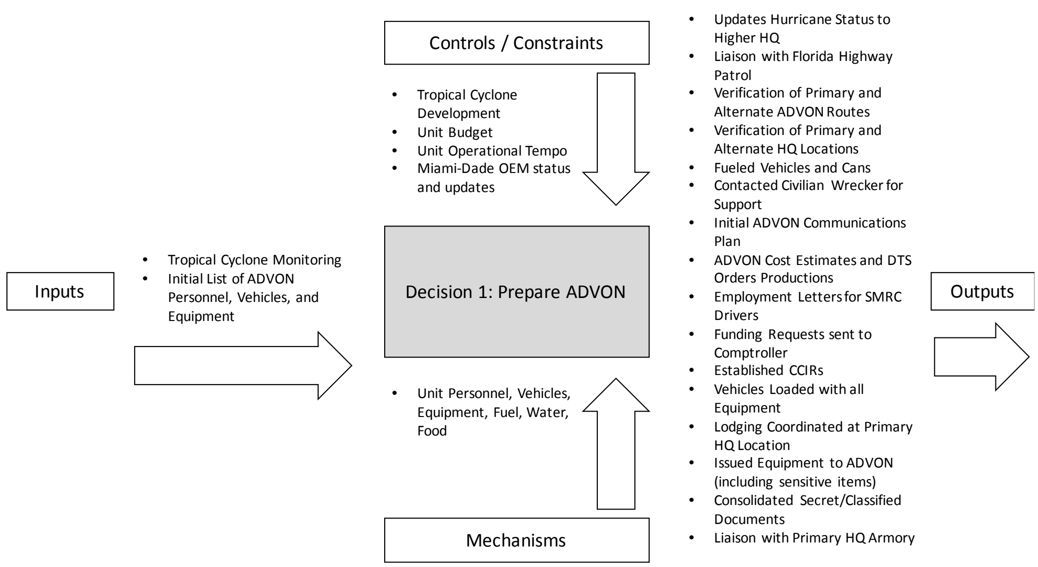


Figure 21. Functional ICOM Analysis of Decision 1: Prepare ADVON

Table 1. ICOM Chart for the MFRHTC HDS

Inputs, Controls and Constraints, Outputs, and Mechanisms Chart for Hialeah MFRHTC					
Index	Decision (time to complete)	Inputs	Controls / Constraints	Mechanisms	Outputs
1	Prepare ADVON (12 hours to complete)	Tropical cyclone monitoring Initial list of ADVON personnel, vehicles, and equipment	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Liason with Florida hughway partol for police escort of ADVON Determine and verify primary and secondary routes for ADVON Determine and verify primary and secondary alternate headquartes locations Fuel all vehicles and fuel cans Contract civilian wrecker support for disabled ADVON vehicles Initial ADVON comunications plan ADVON cost estimates and initial DTS orders production for personnel Weapons qualifications check for force protection personnel Employment letters for SMRC drivers Funding request sent to comptroller Review and establish CCIRs Load vehicles with ADVON gear, equipment, and containers Coordinate lodging for ADVON Issue ADVON weapons, ammo, sensitive items Liason with alternate headquarters locations armory for sensitive items storage Prepare communications equipment Consolidate secret/classified paperwork/data
2	Storm Proof the HTC and Personnel Property (24 hours for each)	Tropical cyclone monitoring Identify vehicles and equipment not going on ADVON Identify inclement weather containers	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Update accountability and recall rosters Update unit communication pla and notify all personnel Coordinate force protetion plan and brief to personnel Ensure all debris cleaned up around HTC Inspection of all section's area to ensure storm proofing is complete Communicate entitlement to all personnel Personnel issued food, water, force protection gear Personnel storm proofed HTC and personnel Property Secure all vehicles and equipment that will be left ourdoors
3A	Deploy the ADVON and Authorize a Voluntary Evacuation (12 hours)	Tropical cyclone monitoring Primary and secondary routes for ADVON Primary and secondary alternate headquartes locations Approved list of ADVON personnel, vehicles, and equipment Final ADVON comunications plan Issued personnel DTS and MROWS Storm proof HTC and personnel property order	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Linkup with Florida hughway partol for police escort of ADVON Linkup with civilian wrecker support for disabled ADVON vehicles Authorized voluntary evacuation order issued OPSEC, convoy, and commanders birefs given to ADVON Vehicle and sensitive item checks Alert local police that all weapons and ammo have been moved Ensure WEX card is with ADVON ADVON deployed and voluntary evacuation authorized Update personnel accountability
3B	Prepare and Standup the RBE (12 hours)	Tropical cyclone monitoring Updated personnel roster Finalized RBE veicles, equipment, and gear lists Storm proof HTC and personnel property order	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Conduct frost call Recall roster finalized All RBE personnel have weapons qualifications on file All HTC watch lists verified, finalized, and distributed to personnel Weapons, ammo, and all force protection gear issued to RBE Commanders safety brief issued Section OIC walkthough of areas Finalized travel orders for potential evacuation RBE stood up Food, water, and additional supplies for 1 week staged
4A	Secure the HTC and Issue a Mandatory Evacuation (2 hours)	Tropical cyclone monitoring Final recall roster Deploy ADVON order or prepare and standup RBE order	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Final HTC inspection conducted/walkthough HTC lockdown Personnel ordered to evacuate
4B	Secure the HTC and Shelter in Place (1 hour)	Tropical cyclone monitoring Final recall roster Deploy ADVON order or prepare and standup RBE order	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Final HTC inspection conducted/walkthough HTC lockdown Personnel ordered to shelter in place
5	Transfer Command and Control to the Alternate Headquarters (1 hour)	Tropical cyclone monitoring Deploy ADVON order	Tropical cyclone development Budget Unit operational tempo Miami-Dade OEM status	Personnel Vehicles Equipment Fuel Water Food	Update hurricane status with higher headquarters Command and control temporatly transferred to alternate headquarters

In this process, one can see that the inputs and outputs changed from decision to decision, but the controls, constraints, and mechanisms remain the same.

2. Hialeah HDS Decision Logic

The HDS requires decisions that have an order. The first preparation must be taken before progressing to the second and so forth. When the user makes a decision, it triggers follow on actions. If the user chooses to continue with the simulations and not take a preparation action (decision) at that time, then the simulation continues to the next forecast update and prompts the user for the same decision. The Hialeah HDS decision logic is displayed in Figure 22. The MARFORRES decision logic was displayed in Figure 3. The simulation then continues prompting the user for decisions until all of the preparation steps have been taken or the simulation is complete and the TC has dissipated.

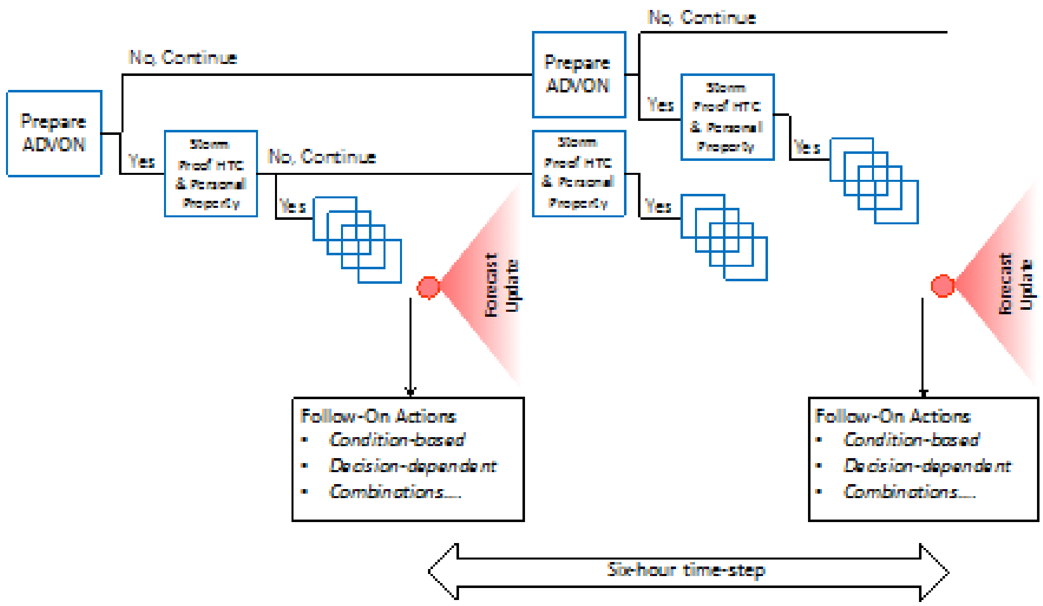


Figure 22. Hialeah HDS Decision Logic. Adapted from Regnier and MacKenzie (2017).

To better illustrate how the key decisions flow, a decision tree was created, displayed in Figure 23. The decision tree shows all the paths, outcomes, and relationships between the decisions that the user can make through the simulation. In the decision tree, it can be seen that if the user selects the "prepare & standup RBE" option then the

“deploy ADVON & authorize a voluntary evacuation” option cannot ever be selected, and vice versa. Choice at the third decision node splits the decision tree into two parallel branches, which is different from the HDS for MARFORRES. Additionally, the user is only offered the option to “transfer command and control (C2)” if they select the decision “deploy ADVON & authorize a voluntary evacuation.” Working backwards through the decision tree, one can see that all of the decisions have prerequisites, which the user must make in the simulation or they will not be prompted for the decision.

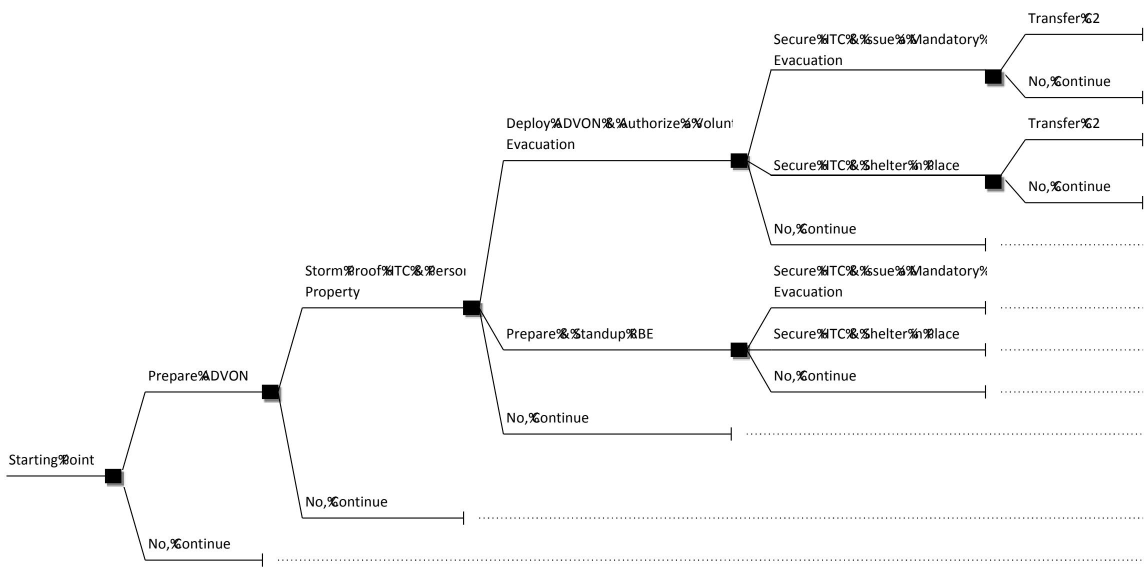


Figure 23. MFRHTC HDS Decision

This chapter detailed how the methodology described in Chapter III was used to examine the problem and details the data and results. The results of the analysis include: a description and illustration of how the DBSS was created, the information it requires, its functions, components, and how it operates. The key decisions of the MFRHTC in Hialeah were analyzed through an ICOM process to determine how the inputs were guided by the controls and constraints and changed by the mechanisms into the outputs. Additionally, the Hialeah HDS logic was detailed along with the decision logic. The next chapter details the conceptual design process for the DBSS and an overall conceptual design so that future versions of the HDS can be developed for different locations.

V. CONCEPTUAL DESIGN FOR THE DBSS

As stated earlier in Chapter III, developing a conceptual design for the system or product is the first and most important step in the design and development process. The conceptual system design develops the basis for understanding of the customer need and establishes the path forward. This chapter will detail a conceptual design for the DBSS so future HDSs can be developed for additional locations. Figure 24 illustrates the conceptual design process as defined by Blanchard and Fabrycky (2011). The steps in Figure 24 will be detailed in this chapter.

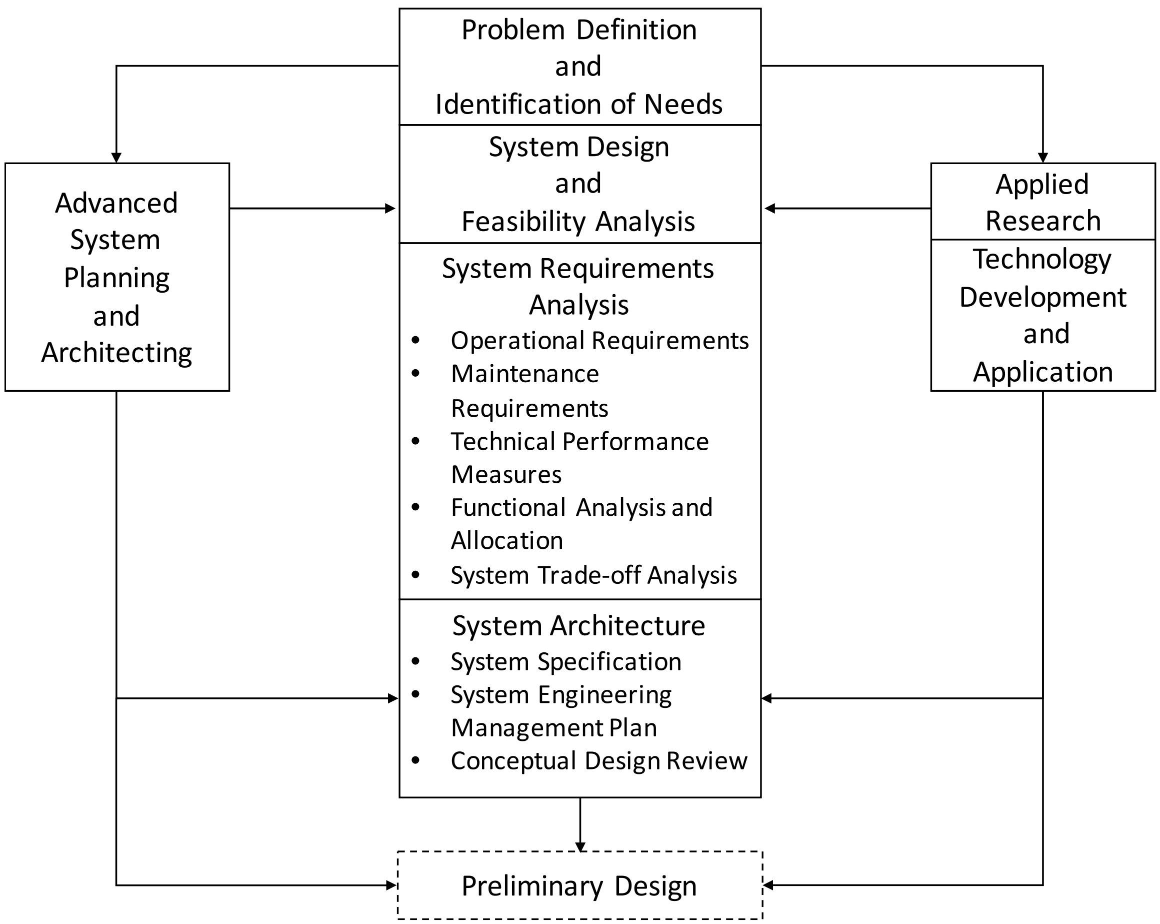


Figure 24. Conceptual System Design Steps. Adapted from Blanchard and Fabrycky (2011).

A. SYSTEM PLANNING AND ARCHITECTING

System planning and architecting begin after a problem and need have been identified for a new or improved system and the system's requirements have been identified. Figure 25 details the early system planning and architecting process in the conceptual design phase. The high-level system architecture contained in the system specification (Type A) forms the foundation for the lower-level architecture preparation and planning. The system specification (Type A) and the systems engineering management plan combine to establish the functional baseline or Milestone I for the project or system. Once Milestone I is reached, the program or system progress onto the preliminary design phase.

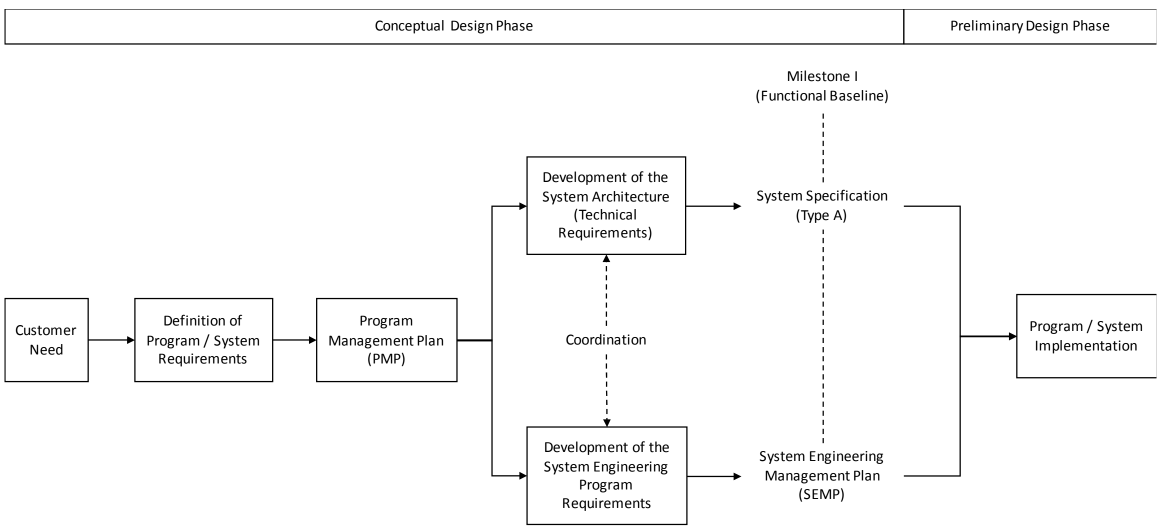


Figure 25. Early System Planning and Architecting. Adapted from Blanchard and Fabrycky (2011).

After MARFORRES requested additional HDSs be built, all stakeholders for the meet, discussed, and defined the HDS system requirements and development timeline, to include the DBSS. Then the NPS team began to develop the system architecture and established a functional baseline.

B. DEFINING AND DEVELOPING THE DBSS'S OPERATIONAL REQUIREMENTS

After an approach or alternative has been selected and a COA is approved, it is necessary to develop the operational requirements of the system. In developing the conceptual design, a systems engineering is used to evaluate commonly listed seven areas that define the DBSS's operational requirements: 1) mission definition, 2) performance and physical parameters, 3) operational deployment or distribution, 4) operational life-cycle, 5) utilization requirements, 6) effectiveness factors, and 7) environmental factors as identified by Blanchard and Fabrycky (2011).

1. Mission Definition

What are the primary and secondary missions of the DBSS? What must the DBSS accomplish, and how does it accomplish it? The DSSs primary mission is to store and send information to the HDS during a simulation. Its secondary mission is to collect the information from the new location. The DBSS must be able to tell the user what information is required, receive the information from the user, check the information for completeness and correctness, tell the user if the information is correct and complete or not, and then store the information. During a simulation, the DBSS must be able to receive a request from the HDS, locate the requested information, and then send the information to the HDS.

2. Performance and Physical Parameters

What are the operating characteristics of the DBSS, such as: size, accuracy, data flow rate, speed, storage capacity? What performance parameters are critical to the system? The DBSS must be of sufficient size that it can run on the available computers and servers of the end user. Since the DBSS uses Excel spreadsheets, which are small and only take up a few megabits, they should not affect any modern computer or operating system from running them. The critical system performance parameters follow the line: 1) the DBSS must receive information from the new location and be able to tell the user if the information is correct and complete within a specific timeframe, 2) the DBSS must

be able to store a specific amount of information, and 3) the DBSS must be able to send data to the HDS during a simulation in a specific timeframe.

3. Operational Deployment or Distribution

How much equipment, personnel, hardware, software, training, facilities, and transportation are required for the expected location of the DBSS? What is being distributed? When does the DBSS become operational? The DBSS requires equipment, personnel, hardware, and software to operate. The DBSS requires some form or interaction, whether automated (such as a webpage) or in person (such as a site visit or video conference) with the new location to inform the user of the information required to construct the DBSS for a new location. It requires a storage device, such as a server or computer, to be stored on and network so that individuals can access the HDS and DBSS. It requires an operating system, such as Windows or OSX, to run Microsoft Office for Excel. It requires a facility for personnel to work from, such as an office. It required several personnel: one person familiar with hurricane preparation operations and emergency management activities to perform a quality check on the information received from the user to ensure the information is complete and correct. This person can perform a site visit if required. It requires a programmer to write the code that will reference the collected information in the DBSS. This programmer can be located almost anywhere within reason, they must have the ability to interact with the person performing the quality check of the DBSS and a manager. One management person is required to oversee the DBSS progress and integration into the HDS. The DBSS must interact with the new location in the design step of the waterfall process model so that it can collect the required information from the user. The DBSS should be distributed as a part of the entire HDS package to the end user. The DBSS becomes fully operational when all of the required information has been collated, is correct, complete, and is integrated with the HDS.

4. Operational Life-Cycle

What is the anticipated time that the DBSS will be in operation? Who will be operating the DBSS? The DBSS will be in operation for the entire operational life-cycle

of the HDS by the end user. Initially, the DBSS will be used by a developer to collect the required information. The operational life-cycle of the DBSS is not known. It will be determined by MARFORRES and the MFRHTC in Hialeah. It is anticipated that it will be used for at least several years, until the scenario build within the HDS become obsolete.

5. Utilization Requirements

What is the anticipated number of hours the DBSS will be used? How will the DBSS be used? The DBSS will always be used in conjunction with the HDS. The anticipated number of hours of the DBSS is not known. It will be determined by MARFORRES and the MFRHTC in Hialeah. MARFORRES uses the HDS a few times per year to train their personnel in group exercises and to train individuals on a case by case basis. The MFRHTC in Hialeah will use the HDS in a similar manner as MARFORRES. After distribution, the end user will operate the DBSS and have the ability to change and adapt the DBSS to their situation or scenario.

6. Effectiveness Factors

Effectiveness factors relate to the figures-of-merit of the system requirements, such as, availability, failure rate, downtime, operator skill level, cost, and schedule. The effectiveness factors must be defined, measurable, and relate to the operational situation. The DBSS is effective as long as it can collect the required information from the new location, check the information for completeness and correctness, inform the user if more information is required, store the information in the correct location, and then enable access to the information during a simulation of the HDS.

7. Environmental Factors

What environment is the DBSS projected to operate in? The DBSS will operate on a server or computer wherever it is being stored and be accessible through the internet. The environmental factors must be acceptable for the server or computer to operate effectively.

C. DBSS'S MAINTENANCE AND SUPPORT REQUIREMENTS

The maintenance and support concept developed should define the characteristics of maintainability, human factors and safety, reliability, constructability, produce ability, sustainability, supportability, and disposability Blanchard and Fabrycky (2011). Since the DBSS is a sub-system of the HDS, the maintenance and support requirements are relatively small. During all life-cycle phases of the HDS, maintaining and supporting the DBSS is simple. The user must ensure that the computer that they are operating on is working and the software operating on the computer or server is supported. Sustaining the DBSS requires the information collected and stored inside it to be evaluated periodically to ensure that it aligns with the HDS scenario for the location. Disposability requires only that the HDS program and DBSS information be archived for possible review in the future or deleted entirely.

D. IDENTIFYING, ESTABLISHING, AND PRIORITIZING TECHNICAL PERFORMANCE MEASURES FOR THE DBSS

Technical performance measures (TPMs) are quantitative values, numbers, or metrics that describe the system performance. They can be predicted, measured, or estimated and are measures of the attributes or characteristics inherent to the design of the system. The objective of a TPMs is to "influence the system design process to incorporate the right attributes or characteristics to produce a system that will ultimately meet customer requirements effectively and efficiently" (Blanchard and Fabrycky 2011, 82). TPMs should be identified and prioritized by the stakeholders, including the customer, designed, producer, suppliers, and key management personnel to ensure that they capture the most important objectives of the system design. Possible TPMs for the DBSS would include:

- processing time (dd:hh:mm:ss) for the system to receive and send information to the user when collecting information
- processing time (milliseconds) for the system to receive a request from the HDS and then locate and send the information during a simulation

- operational availability (99% minimum) when the user wishes to use the HDS
- size (megabits of storage)
- human factors (less than 1% error rate) when determining if the information the user sends is correct and complete

E. FUNCTIONAL ANALYSIS AND ALLOCATING REQUIREMENTS TO COMPONENTS OF THE DBSS

A functional hierarchy, function description, functional flow block diagram, physical block diagram, and components description of the DBSS will be used to explore the underlying "what" a system must do and will help understand the functions, sub-functions, and components of the DBSS and their relationships.

Creating a functional hierarchy for the DBSS defines the basics for a functional analysis and displays a view of the HDS's functional architecture. It organizes the functions into sub-systems in a top-down, highest to lowest logical order, and shows how elements in the systems relate. Though functional hierarchies have significant importance they have several limitations. The most important limitation is the inability to relate and indicate the flow of functions and sub-functions in time and space. FFBDs describe the structure of the system operating requirements into a functional architecture by illustrating organizational and functional interfaces (Blanchard and Fabrycky 2011). Figure 26 illustrates a functional hierarchy with the first and second level functions of the DBSS. Table 2 defines the functions. Figure 27 uses the DBSS functions to create an FFBD for creating a DBSS.

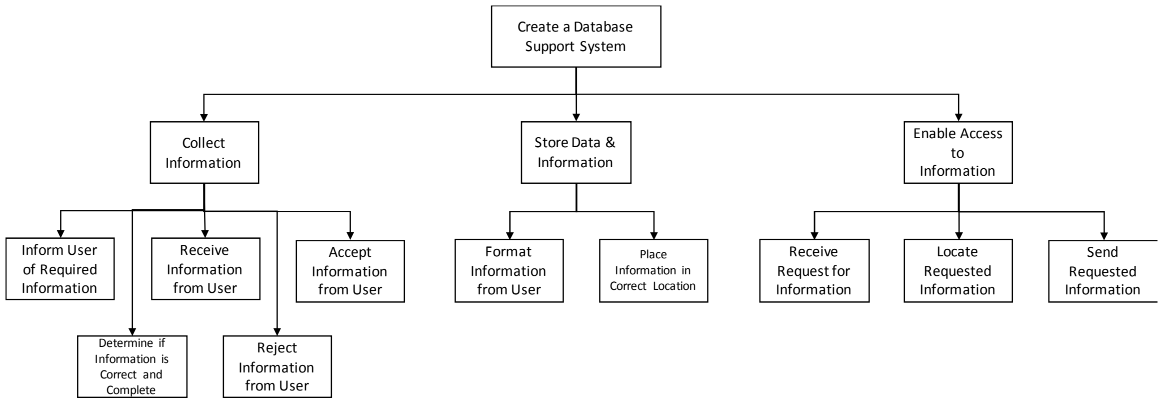


Figure 26. Functional Hierarchy for the DBSS

Table 2. DBSS Function Descriptions

DBSS Functional Descriptions		
Functions		Description
Collect Information		Iterative process of collecting the required information, determining if the information is correct or not, and accepting or rejecting the information
	Inform User of Required Information	Process of telling the user what information the DSS requires
	Receive Information from User	Process of receiving the information from the user
	Determine if Information from User is Correct and Complete	Process of determining if the information received from the user is correct and complete
	Accept Information from User	Process of accepting the information form the user
	Reject Information from User	Process of rejecting the information from the user
Store Data and Information		Process of formatting and storing the data and information received from the user
	Format Information from User	Process of formatting the data and information received from the user
	Place Information in Correct Location	Process of putting the information from the user in the correct location in the DSS
Enable Access to Information		Process of allowing access to the stored information from outside sources
	Receive Request for Information	Process of receiving a request for information
	Locate Requested Information	Process of locating the requested information within the DSS
	Send Requested Information	Process of sending the requested information to the requester

In Figure 27, the DBSS first informs the user of the information required by the DBSS. The user then collects the required information from their planning and operating documents, then sends the information to the DBSS. The DBSS receives the information, formats it, places it into the correct storage location, and then determines if the

information is complete and correct. Complete and correct insures that all information required was received and is accurate. If the information is complete and correct, the DBSS accepts the information and stores it in its storage system. If the information is not complete and correct, the DBSS rejects the information and informs the user and requests additional information. This loop continues until the user sends the correct information in its completeness to the DBSS. After all of the information has been accepted, the DBSS waits until a simulation is being conducted and the HDS requests information from the DBSS. Then the DBSS receives the request, locates the information, and sends the information to the HDS. The DBSS continues to do this throughout the simulation until it is complete.

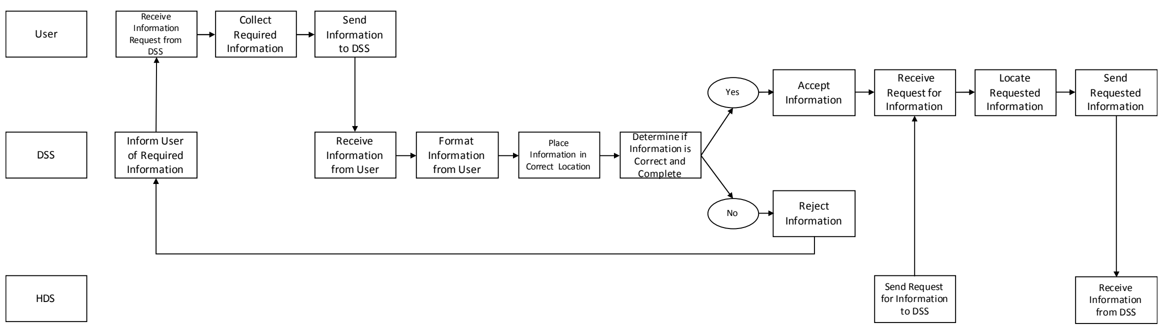


Figure 27. FFBD for Creating the DBSS

After creating a functional hierarchy, defining the functions, and creating a FFBD for creating the DBSS, the components of the DBSS begin to materialize. Figure 28 illustrates a physical flow block diagram where the components of the DBSS can be seen. Physical flow block diagrams are similar to functional hierarchies except they show the components instead of the functions. Table 3 describes the components.

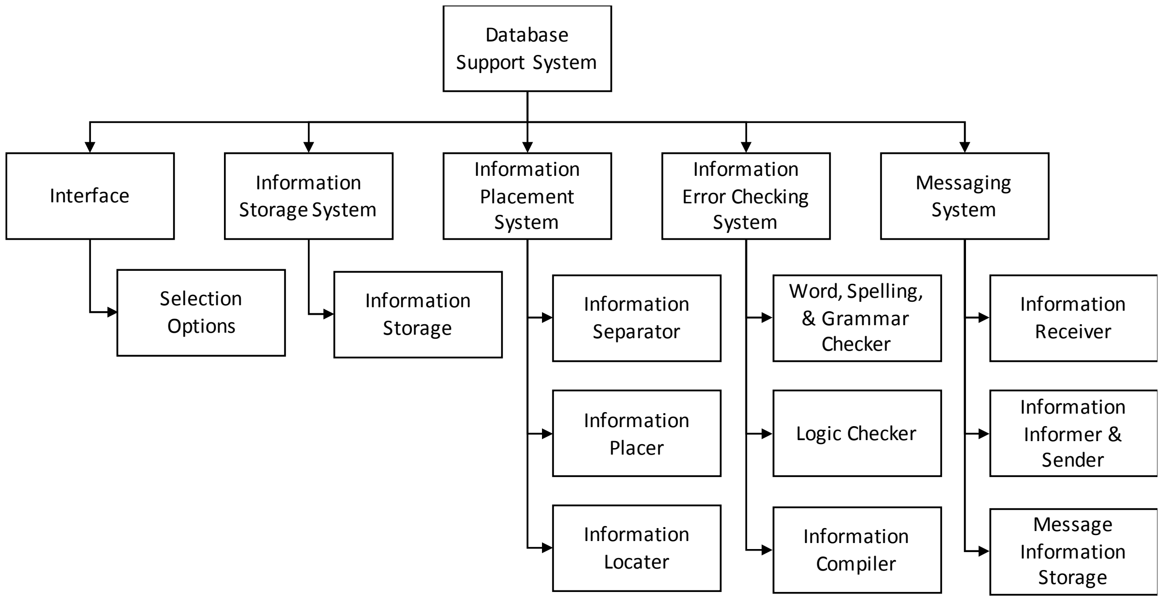


Figure 28. Physical Block Diagram for the DBSS and its Components

Table 3. DBSS Component Descriptions

DBSS Component Descriptions		
Components		Description
Interface		Place where the user interacts with the DSS (webpage or server location)
	Selection Options	Options the user has to select from on the interface (links or buttons on the webpage)
Information Storage System		Storage system for the DSS
	Information Storage	Place where the information collected from the user is stored (spreadsheets)
Information Placement System		System that places the information collected from the user into the appropriate location
	Information Separator	Separates the information into the correct storage area (spreadsheet)
	Information Placer	Places the information after it has been separate into the correct location inside the storage system (inside the spreadsheet)
	Information Locator	Locates information in the storage system
Information Error Checking System		Systems that checks the information for error is grammar, spelling, and logic (it is worded right, spelled correctly, and does it make sense)
	Word, Spelling, & Grammar Checker	Spelling and grammar checking (think of it use in Microsoft Word)
	Logic Checker	Checks information to determine if it makes sense
	Information Compiler	Compiles information into after spelling, grammar, and logic checking back into its storage location
		If not complete and correct sends notice to messaging system
Messaging System		System that sends and receives information to the user
	Information Receiver	Receives information (inbox)
	Information Informer & Sender	Sends information (outbox)
	Message Information Storage	Storage system for the messaging service (log record to review)

All functions identified in the functional hierarchy are associated with at least one component that can be displayed in a traceability matrix. In the traceability matrix, the functions are listed on the left and the components at the top. Functions and components that are associated together are designated with an "X." Table 4 displays the traceability matrix for the DBSS. If a function or component was not listed with an "X," then it is not required or the matrix is incomplete.

Table 4. Traceability Matrix for the DBSS

Traceability Matrix for the DBSS						
Functions		Components				
		Interface	Information Storage System	Information Placement System	Information Error Checking System	Messaging System
Collect Information						
	Inform User of Required Information	X				X
	Receive Information from User	X	X			X
	Determine if Information from User is Correct and Complete				X	
	Accept Information from User	X			X	X
	Reject Information from User	X			X	X
Store Data and Information						
	Format Information from User		X	X	X	X
	Place Information in Correct Location		X	X	X	
Enable Access to Information						
	Receive Request for Information	X				X
	Locate Requested Information		X	X		
	Send Requested Information	X				X

Further detail the mapping of functions to components leads to functional packaging. This method details how the operational modes of the DBSS related to the functions, sub-functions, and components. Figure 29 illustrates this process.

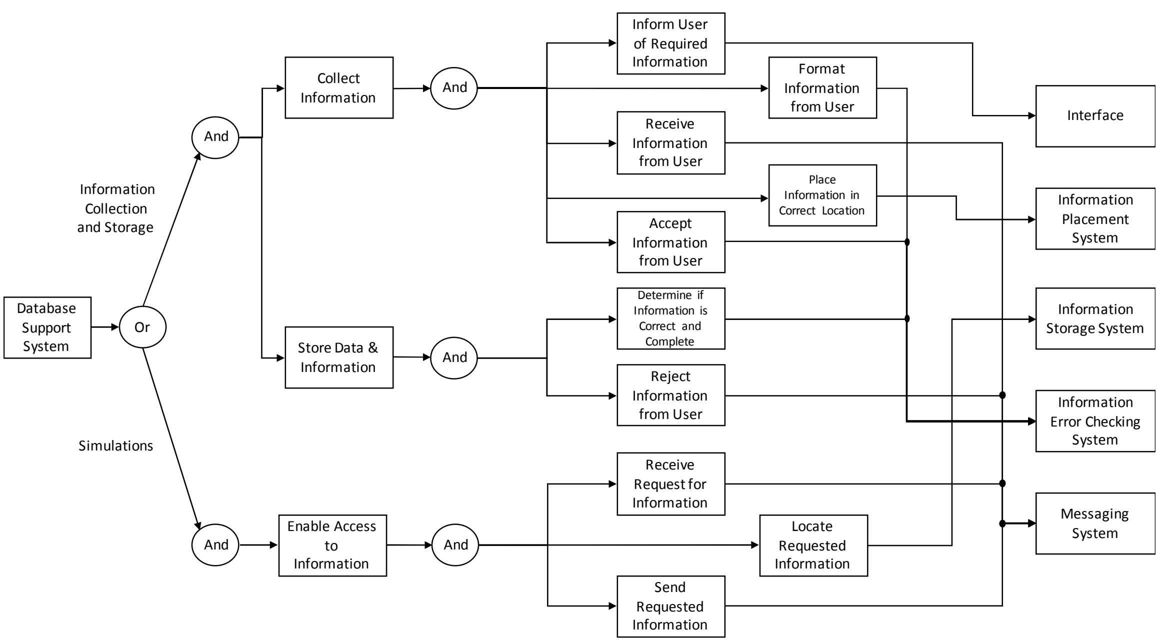


Figure 29. Functional Packaging of the DBSS into Components

F. DBSS SYSTEM TRADE-OFF ANALYSIS

A system trade-off analysis is conducted in order to make decisions regarding the evaluation of technologies, components, subsystems, packaging schemes, degree of automation, type of testing and evaluation, maintenance and support processes, storage locations, logistics, and so on in the system design process. To accomplish a system trade-off analysis the problem must be defined, then measures identified to which the alternatives will be measured (the applicable TPMs), an evaluation technique is selected to model the process, each alternative is evaluated, then a sensitivity analysis is conducted, and finally a determination on the best alternative (Blanchard and Fabrycky 2011). Figure 30 illustrates the system an example trade-off analysis process. The trade-off analysis for the DBSS was relatively simple, either modify the programming code and change the information inside the code for each new location or create a static storage system (the DBSS) that the programming code would reference. Since the latter was a well-established solution with which the developers (NPS team) were familiar, it was chosen.

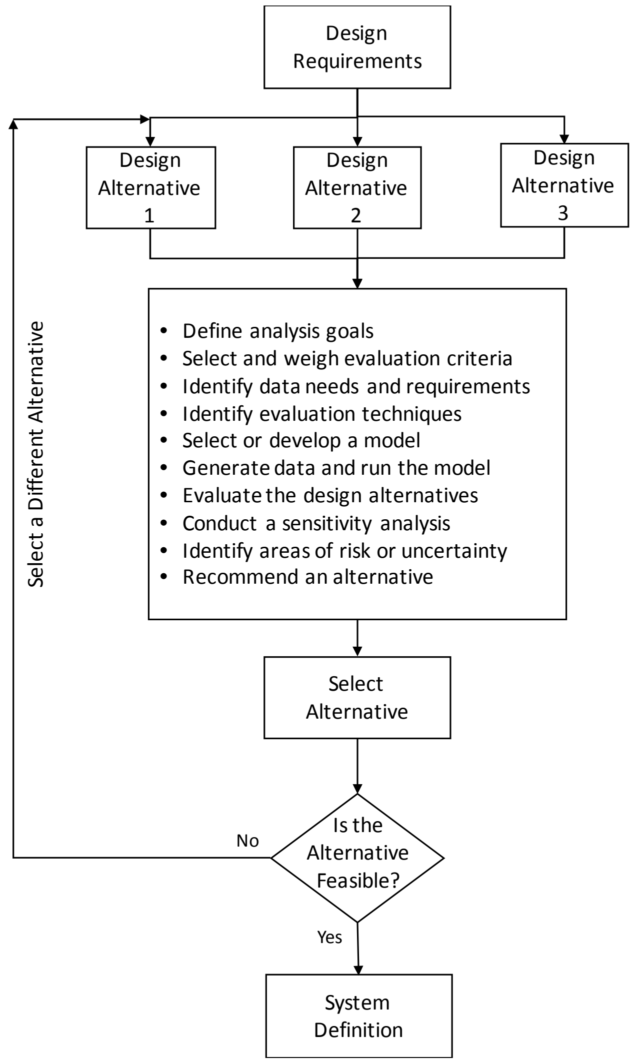


Figure 30. Example Trade-off Analysis Process. Adapted from Blanchard and Fabrycky (2011).

Due to the degree of human interaction with the DBSS, the degree of automation should be examined to determine what can be automated and what requires a human. In future versions of the HDS (version three and beyond), automated systems can fulfill several tasks that in previous versions were conducted by humans. Primarily the data collection methods can be streamlined by the use of automation. Site visits to new locations are not required to collect information. A webpage listing the spreadsheets with a detailed description and examples can be posted to show the new location and what information is required. If a webpage is not used, then an email, telephone conversation,

or video conference can be conducted. An artificial intelligence or program can process the information and determine if it is complete, but a human must conduct a sanity check and verify that the information is correct. All of these methods can save time, money, and resources.

G. DBSS CONCEPTUAL DESIGN REVIEW

The conceptual design review is an evaluation function that ensures that the system design is correct and can progress to the next step, preliminary design. Figure 31 illustrates the overall conceptual design for the DBSS.

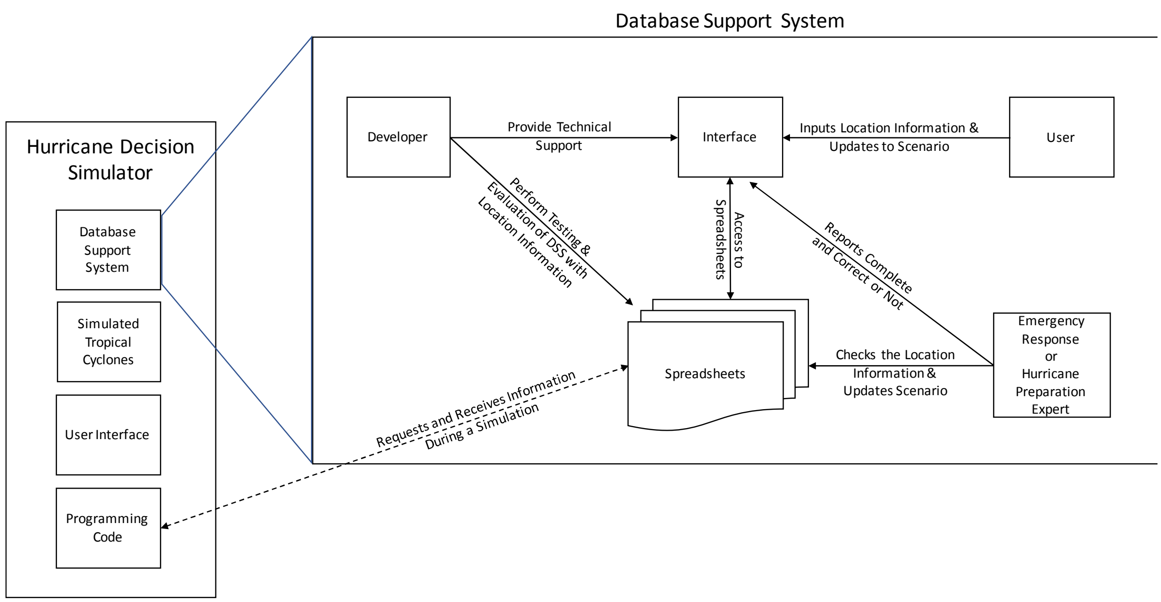


Figure 31. DBSS Conceptual Design

This step includes both reviewing the day-to-day operations as well as the data and documentation of the overall system design. During this process, the design is reviewed for compliance with the system requirements and if the design satisfies the requirement it is approved and progresses. If the design does not meet the system requirements, corrective actions are taken to initiate a design review to determine a path forward and what must be done to correct the issues.

This chapter detailed the steps of a conceptual design for the DBSS as defined by Blanchard and Fabrycky (2011). Future versions of the DBSS should use this conceptual design and the conceptual design process as a basis for developing the DBSS further and possible automations of its functions.

VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY AND CONCLUSIONS

This thesis focused on the MFRHTC located in Hialeah, Florida, and used it to accomplish four objectives: 1) use a mission engineering analysis process to evaluate and analyze the decisions and actions that the commander and staff of the MFRHTC in Hialeah must make in preparation for a hurricane and possible evacuation of the HTC, 2) use the decomposition of the mission space to identify the types of information and resources necessary for these operations, 3) create a static database for the development of future HDSs, and 4) detail and create a conceptual design for the DBSS.

Both mission and system engineering are powerful tools that can be used to examine the information and resources requirements and the decision and actions that the commander of a MFRHTC must make in hurricane preparation operations. The information, decisions, and actions feed into the spreadsheets of the DBSS. The DBSS is essential to the further development of the HDS because it allows for an easier collection, handling and storage of the information, decisions, and actions required in hurricane preparation operations. In order to create a functioning DBSS, it is necessary to structure the requirements process of the DBSS. Doing so illustrates the functions and components required for the DBSS. Creating a conceptual design for the DBSS makes it easier to understand and develop DSSs for the MFTHTC and other organizations.

The methodology in Chapter III describes how ME, SE, and the MDMP can be applied to decompose the HDS and develop a DBSS for future HDSs. Additionally, the methodology helped analyze the methods, purpose, and type of data and information required for hurricane preparation operations. Chapter III also explains how SE, the U.S. Army design methodology, and the MDMP combine together to form the ME process.

The analysis in Chapter IV details how the methodology was used to examine the problem and determine the information requirements and results. It identifies the type of information and resources necessary for hurricane preparation operations, along with the key decisions and follow on actions that the commander can make. The information was

included in the spreadsheet of the DBSS. Chapter IV also breaks down the DBSS, illustrating both the functions and components of the DBSS, then maps the functions to the components.

Determining the information requirements, key decisions, and actions that the MFRHTC in Hialeah must take during hurricane preparation operations was critical to the development of the DBSS. The key decisions include: 1) Prepare the ADVON party, 2) Storm proof the HTC and personal property, 3A) Deploy the ADVON party to the alternate command and control location and authorize a voluntary evacuation, 3B) Prepare and stand up the RBE, 4A) Secure the HTC and issue a mandatory evacuation order, 4B) Shelter in place, and 5) Transfer command and control to the alternate headquarters. These key decisions enabled the construction of a decision tree, which determined the decision logic and architecture of the programming code.

Chapter V details a conceptual design for the DBSS, which establishes the foundation for understanding the customer need. The current version of the HDS was specific to MARFORRES in New Orleans. It could not adapt to new locations; therefore, the HDS needed to be transformed into a version that would be adaptable to different locations. System planning and architecting was conducted to establishing a system engineering management plan and functional baseline for the DBSS. A system trade-off and feasibility analysis was detailed, resulting in two alternatives that were examined: 1) replacing the location specific information in the programming code or 2) removing the location specific information from the code and placing it in a storage location where the code you reference the information when needed during a simulation. Alternative two was chosen because it was already a well-established practice in the software industry. The system operating requirements were examined and determined by evaluating the DBSS through the commonly listed seven areas: 1) mission definition, 2) performance and physical parameters, 3) operational deployment or distribution, 4) operational life-cycle, 5) utilization requirements, 6) effectiveness factors, and 7) environmental factors as identified by Blanchard and Fabrycky (2011). The maintenance and support requirements of the DBSS were determined to be small throughout the HDS life cycle, requiring a storage device to store the program, a computer to run the program, and

periodic updates to the information in the DBSS to ensure it still applies to the operational scenario. Lastly, a conceptual design review was detailed to ensure that the alternative design selected is correct and can progress to the next step, preliminary design.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Beyond this thesis, areas of future research and work should begin with a preliminary design, then continue to a detailed design of the DBSS. Additionally, and detailed design should be completed for the HDS to ensure proper documentation is captured. If any new products or developments are added to the HDS, they should have a conceptual, preliminary, and detailed designs completed.

Areas of further research and work for the HDS may include: human factors analysis of the user interface, finding additional uses and applications of the HDS, and the use of an artificial intelligence or program to assist the user in making real-time decisions during a simulation. Human factors analysis involves studying the user interface to determine areas of improvement. For these studies, it is important to understand the human eye movements in relation to the visual view, which allows researchers to measure where the eyes are looking, for how long, what the user is focused on, and how often areas in the visual view are revisited. Exploring the uses and applications of the HDS opens the door to finding different organizations that could benefit from the HDS, such as the United States Army Corps of Engineers, the Federal Emergency Management Agency, and numerous cities and emergency management center. Additionally, evaluating the current uses of the HDS at MARFORRES can provide useful information and possible improvements. Lastly, a study on the use of an artificial intelligence to assist the user in making decisions during a simulation. This tool would have to be in context with developing decision support for real-time decisions. Additionally, an artificial intelligence could be developed to aid in measuring performance of the user, identifying optimal (good or bad) decisions and use the information to provide more direct feedback to the user.

Areas of further research and emphasis for the DDS should include the creation of a digital interface, such as a web page, and a study of the use of automation to collect location information from the user. Using a digital interface allows the user and human to interact without the cost of traveling to meet one another. Currently, a human is required to receive the location information from the user, input the information into the correct spreadsheet, and check to see if the information is correct and complete. A study about the use of an artificial intelligence to help automate the information collection, placement, and storage processes would reduce the amount a human is involved and save costs.

APPENDIX. HURRICANE DECISION SIMULATOR – DETAILED SIMULATION EXAMPLE

This appendix details an example of one simulation in the MARFORRES HDS. It allows the reader to experience the HDS without using the program. The MARFORRES HDS is available from http://eddy.nps.edu/hurricaneSim/simulation. The simulation starts in Figure 32 with the initial TC update and the user is prompted with the first decision, deploy the ADVON.

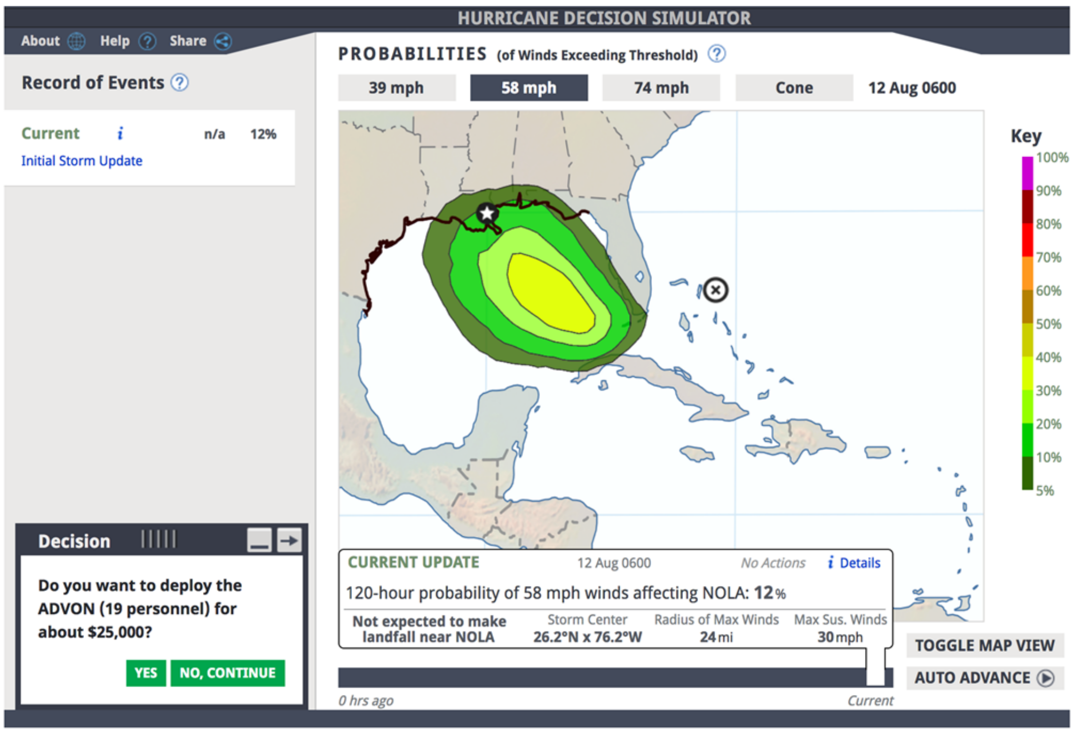


Figure 32. Simulation Start. Source: U.S. Marine Forces Reserve (2016).

The user decides not to make the decision and continues the simulation. The user continues through the first three TC updates, shown in Figure 33 through Figure 35, before he or she decides to make the first decision. Throughout the simulation, the 58-mph wind speed probability is displayed on the map, which the user uses to determine if and when to make a decision. The user can also use the wind speed probabilities of 39 and 74 mph along with the first error winds cone probability. TC updates are presented in

six-hour increments with updated time to land fall predictions and wind speed probabilities of what the user has selected.

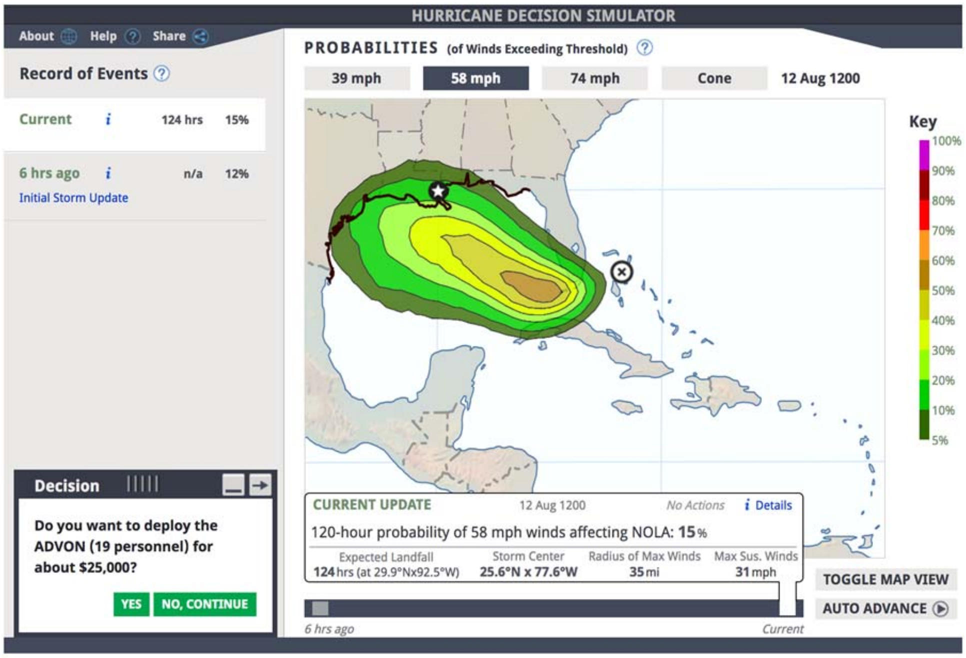


Figure 33. First Update. Source: U.S. Marine Forces Reserve (2016).

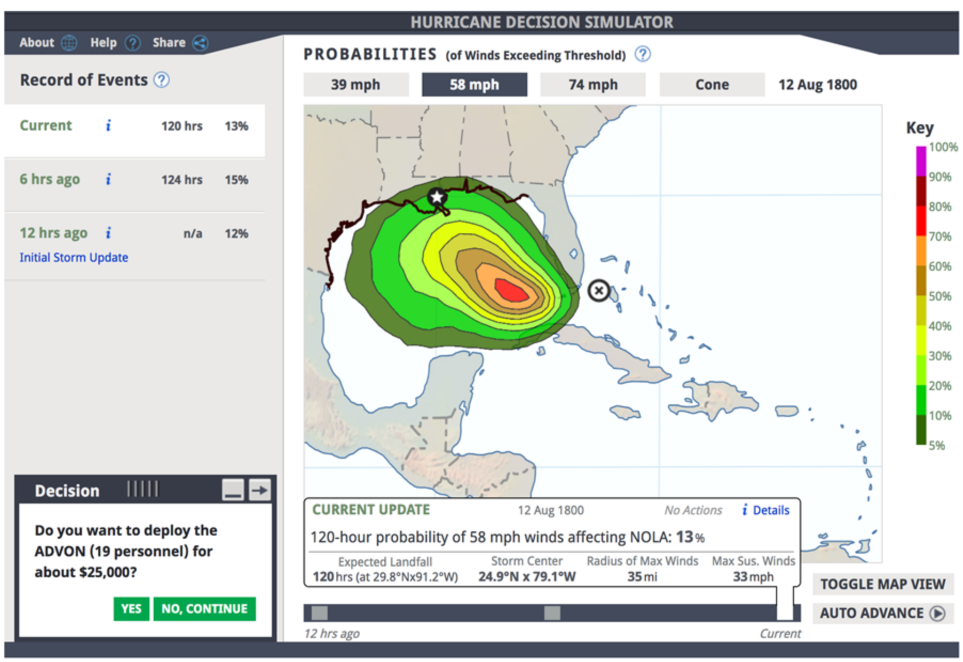


Figure 34. Second Update. Source: U.S. Marine Forces Reserve (2016).

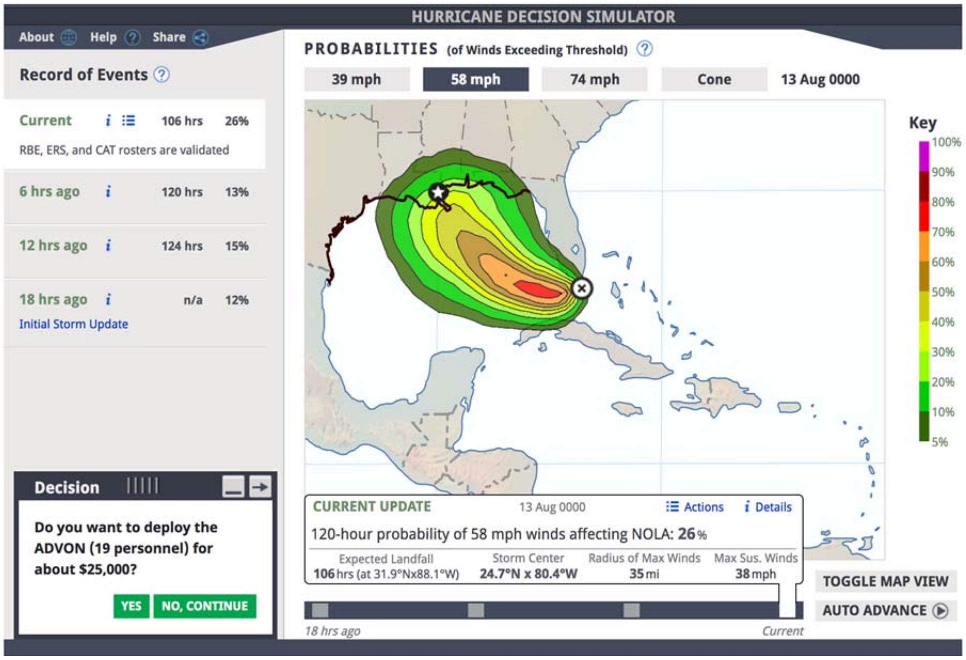


Figure 35. Third Update. Source: U.S. Marine Forces Reserve (2016).

After the user sees the third TC update, the user decided to make the first and second decisions, deploy ADVON to the alternate headquarters location and deploy Liaison Officers to the local agencies based on a 26% probability of receiving 58 mph winds at 106 hours to land fall, shown in Figure 36 and Figure 37. The user then continues through the fourth, fifth, and sixth TC updates, seen in Figure 38 through Figure 40.

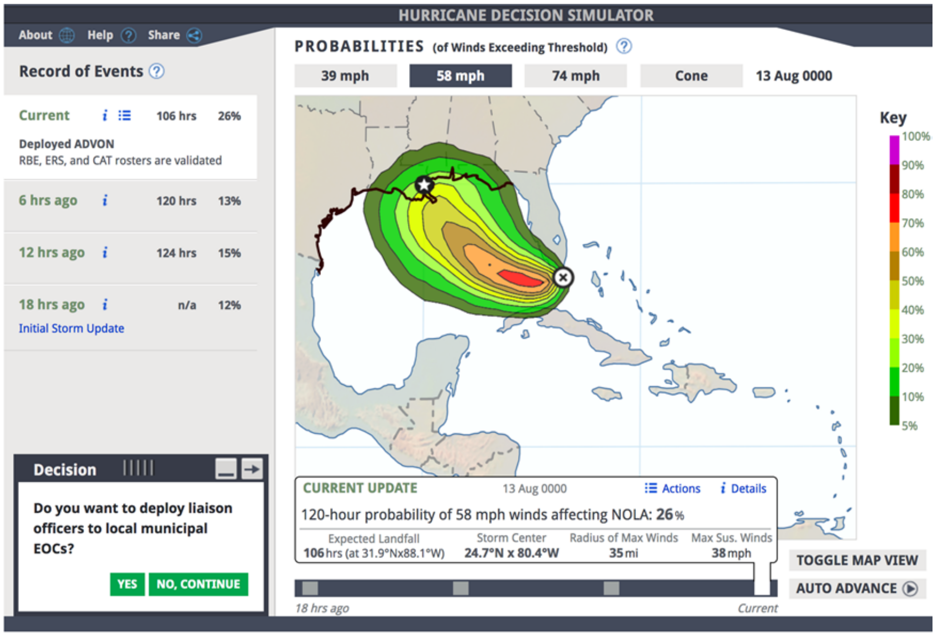


Figure 36. Third Update with ADVON Deployed. Source: U.S. Marine Forces Reserve (2016).

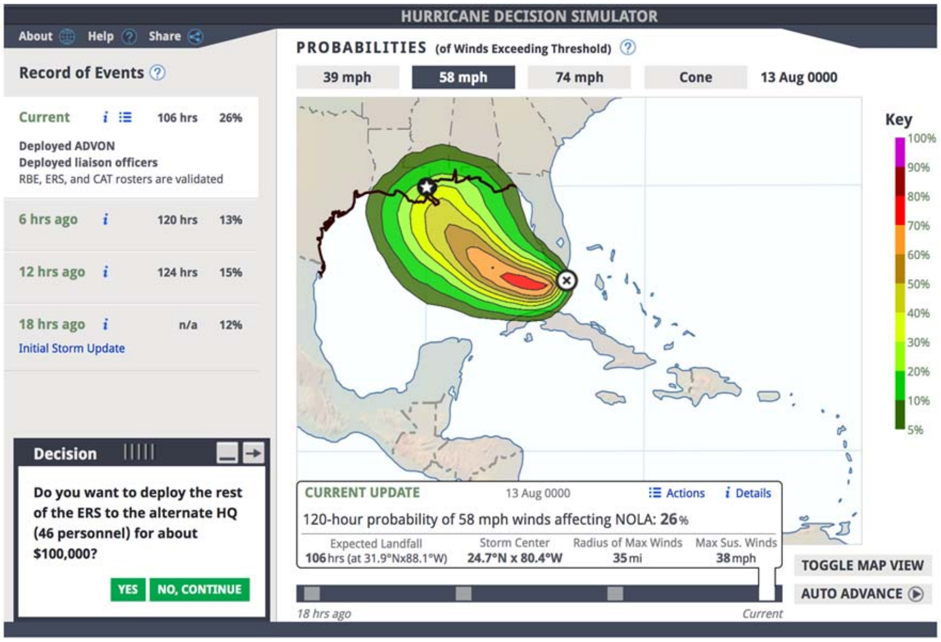


Figure 37. Third Update with Liaison Officers Deployed. Source: U.S. Marine Forces Reserve (2016).

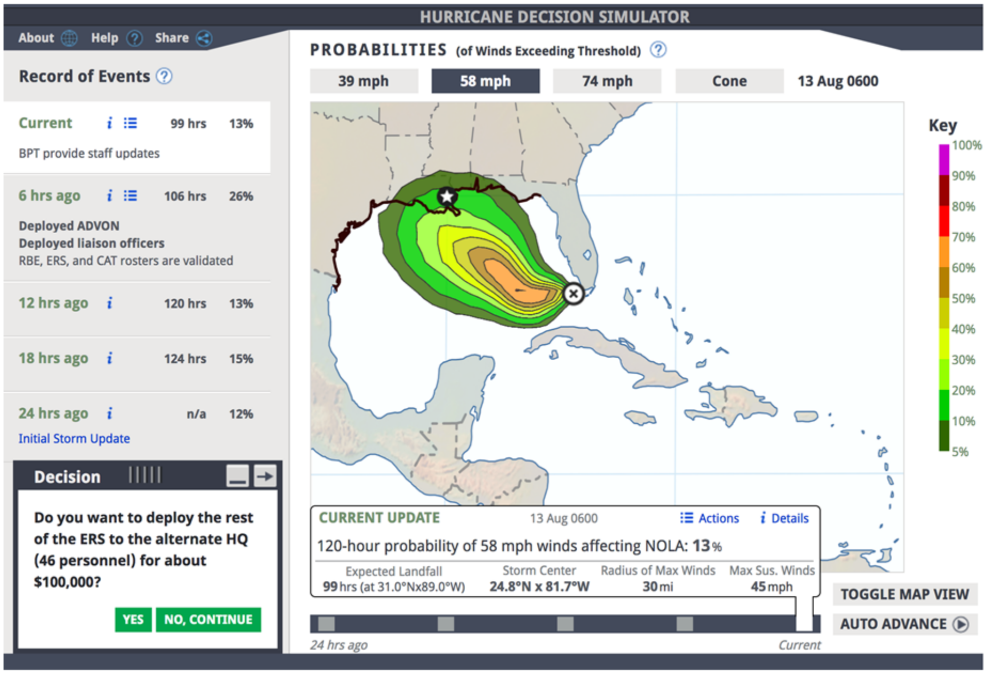


Figure 38. Fourth Update. Source: U.S. Marine Forces Reserve (2016).

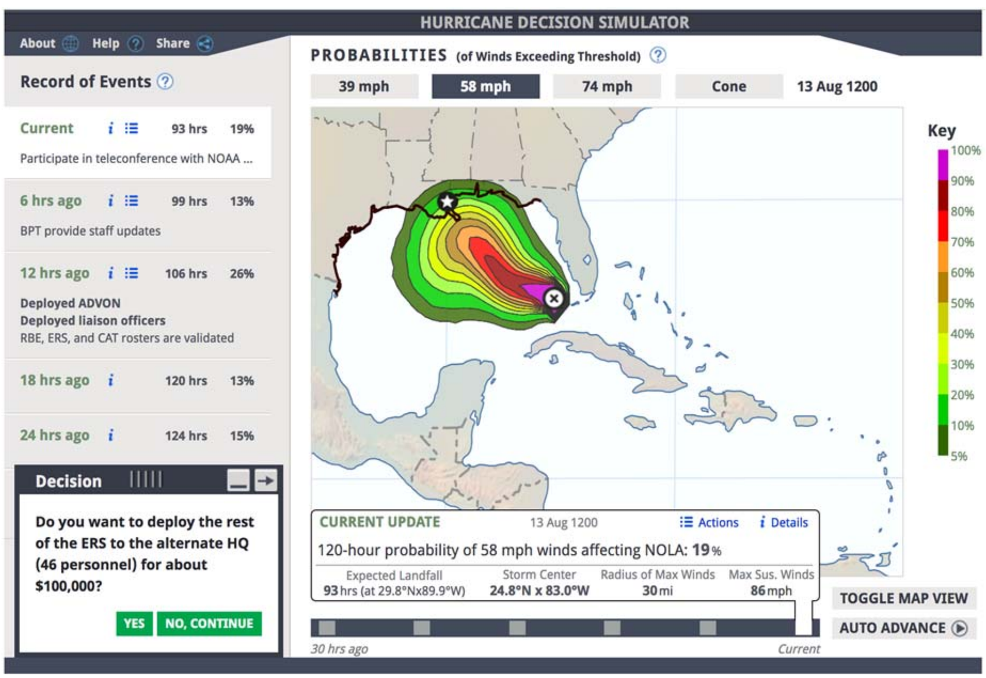


Figure 39. Fifth Update. Source: U.S. Marine Forces Reserve (2016).

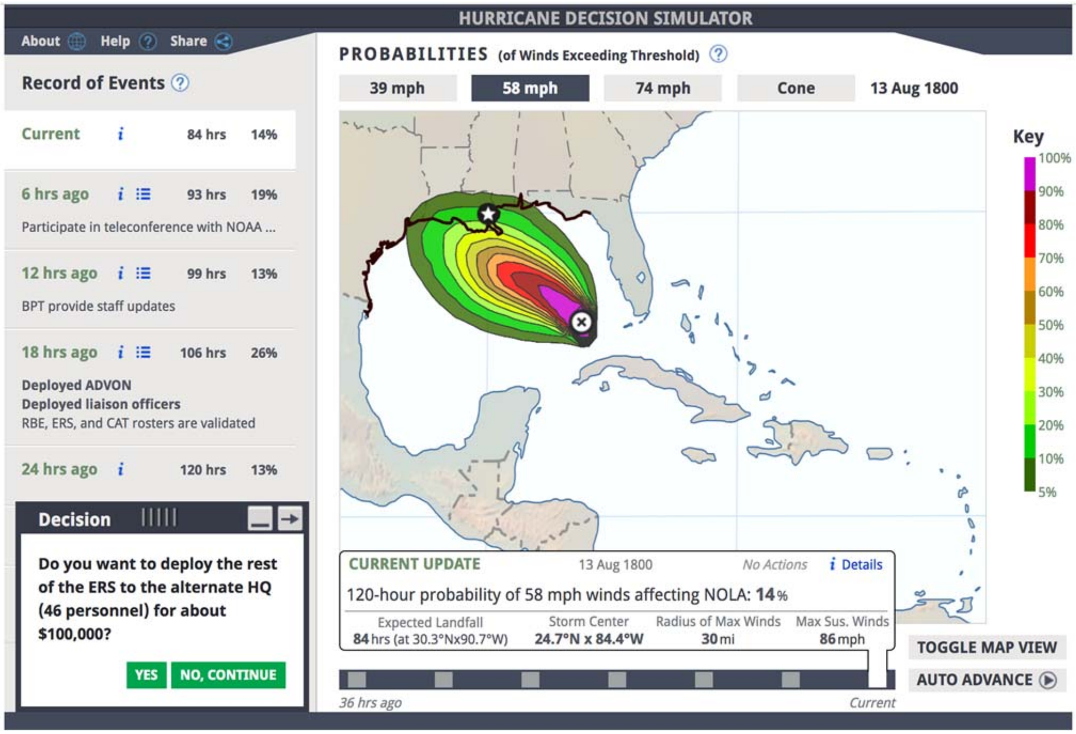


Figure 40. Sixth Update. Source: U.S. Marine Forces Reserve (2016).

After the sixth TC update, the user decided to make the decision to deploy the rest of the ERS team to the alternate headquarters location, based on a 14% probability of receiving 28 mph winds at 84 hours to landfall. The user then continues through the seventh and eighth TC update, shown in Figure 41 and Figure 42.

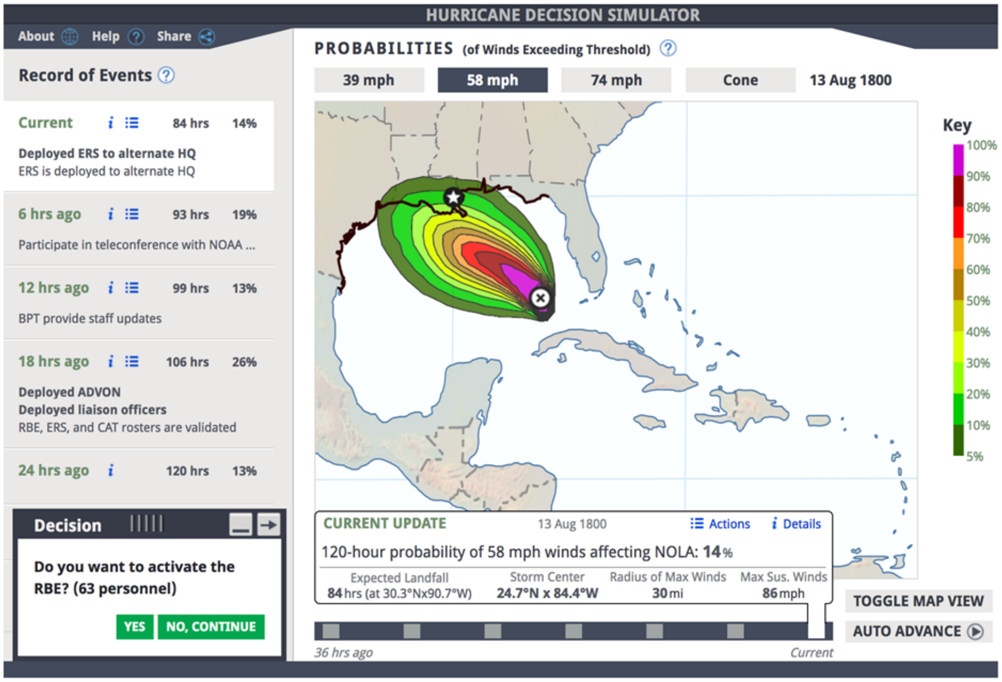


Figure 41. Seventh Update. Source: U.S. Marine Forces Reserve (2016).

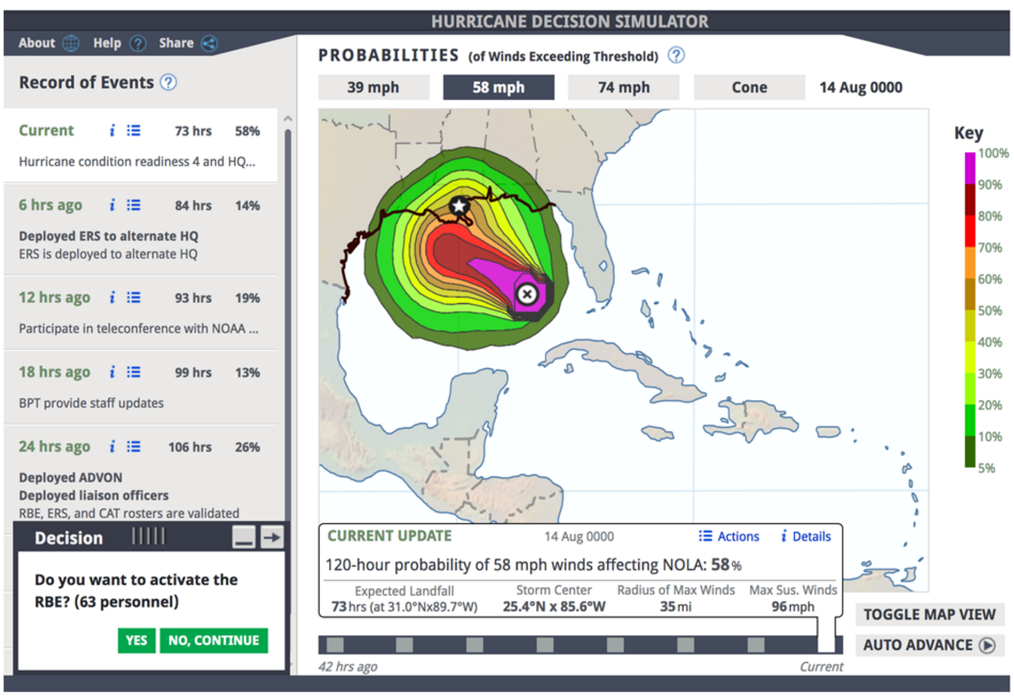


Figure 42. Eighth Update. Source: U.S. Marine Forces Reserve (2016).

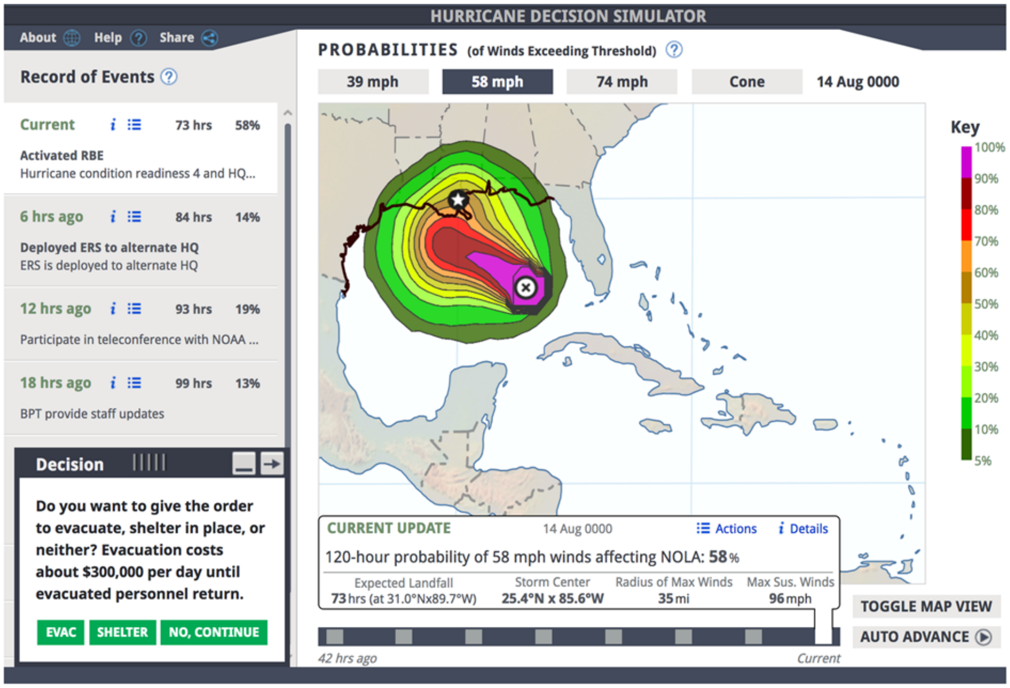


Figure 43. Ninth Update with RBE Activated. Source: U.S. Marine Forces Reserve (2016).

After the ninth TC update the user decides to make the decision to activate the RBE, based on the 58% probability of receiving 58 mph winds at 73 hours before land fall, shown in Figure 43.

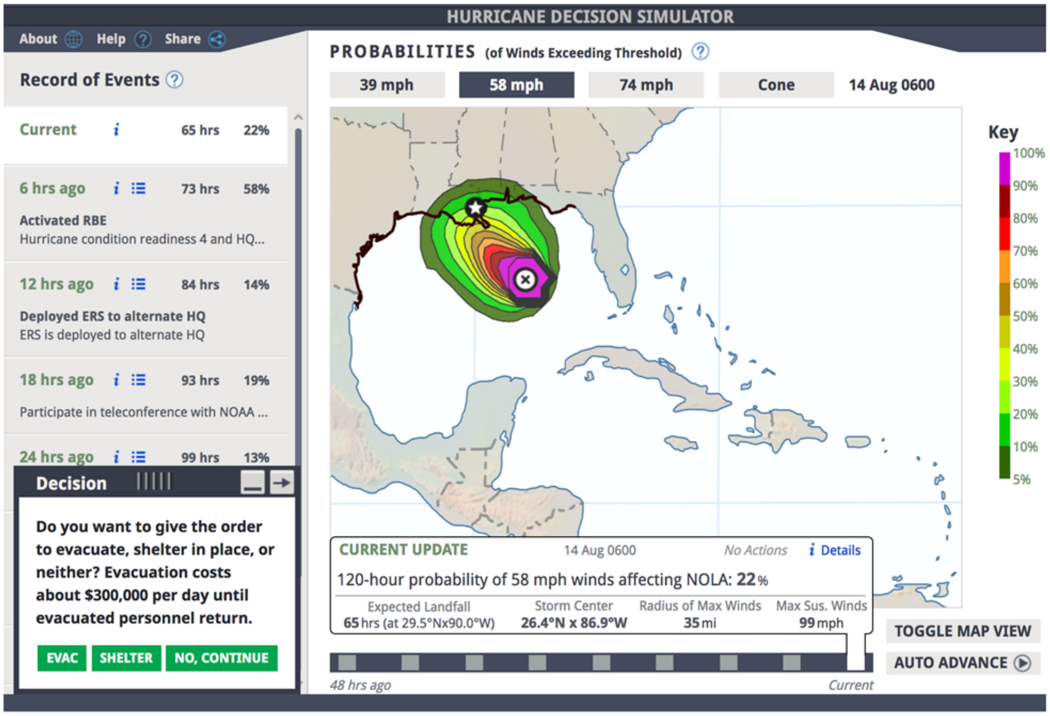


Figure 44. Tenth Update. Source: U.S. Marine Forces Reserve (2016).

After the tenth TC update, shown in Figure 44, the user decided to make the decision to order an evacuation based on a probability of 22% of receiving 58 mph winds at 65 hours before landfall. The user then continues through the eleventh and makes the decision and twelfth TC updates, shown in Figure 45 and Figure 46.

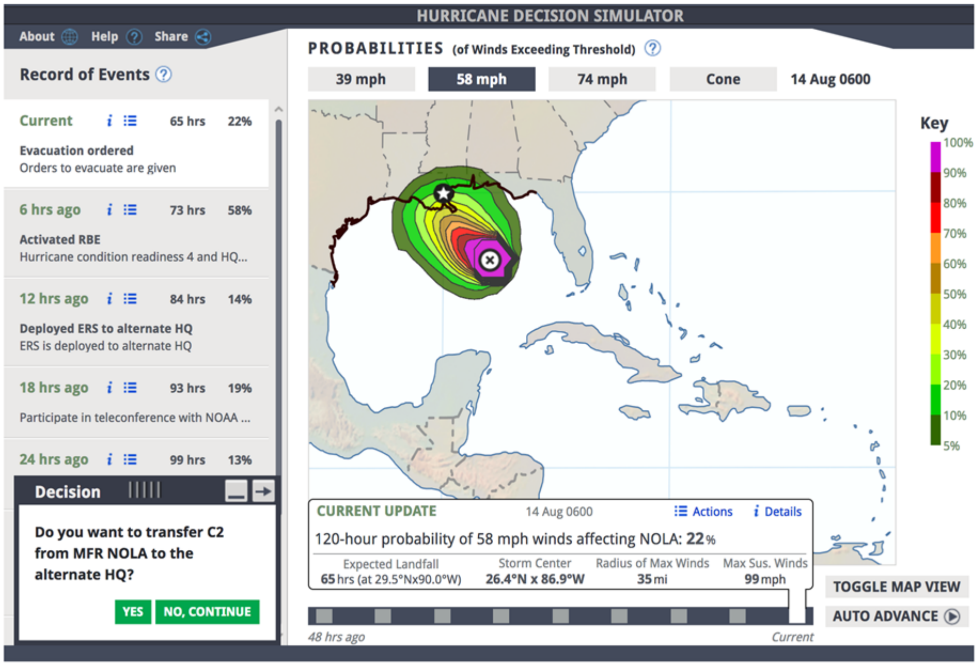


Figure 45. Eleventh Update with Evacuation Order Issued. Source: U.S. Marine Forces Reserve (2016).

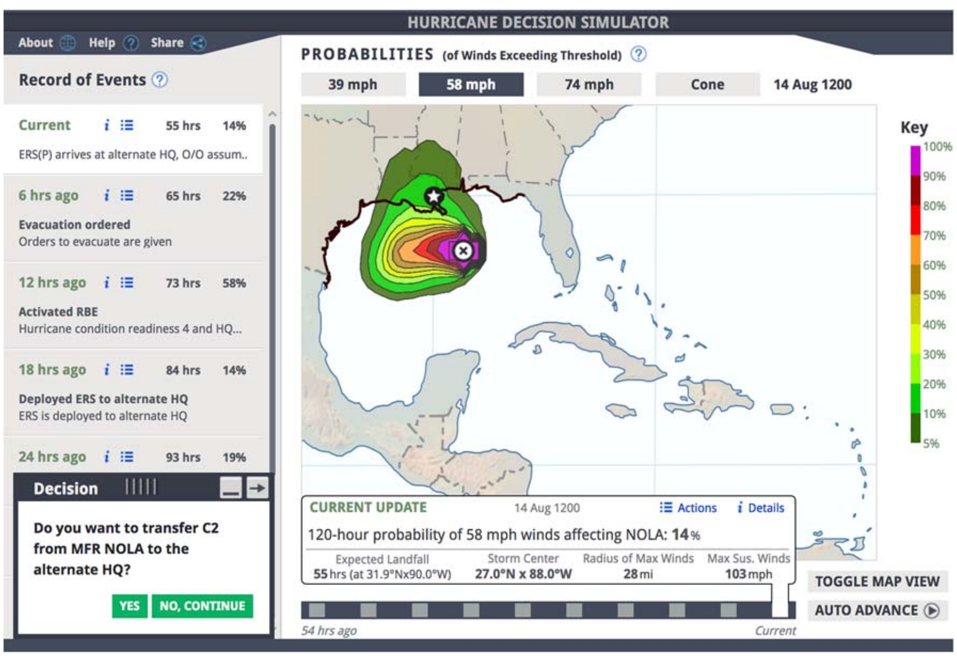


Figure 46. Twelfth Update. Source: U.S. Marine Forces Reserve (2016).

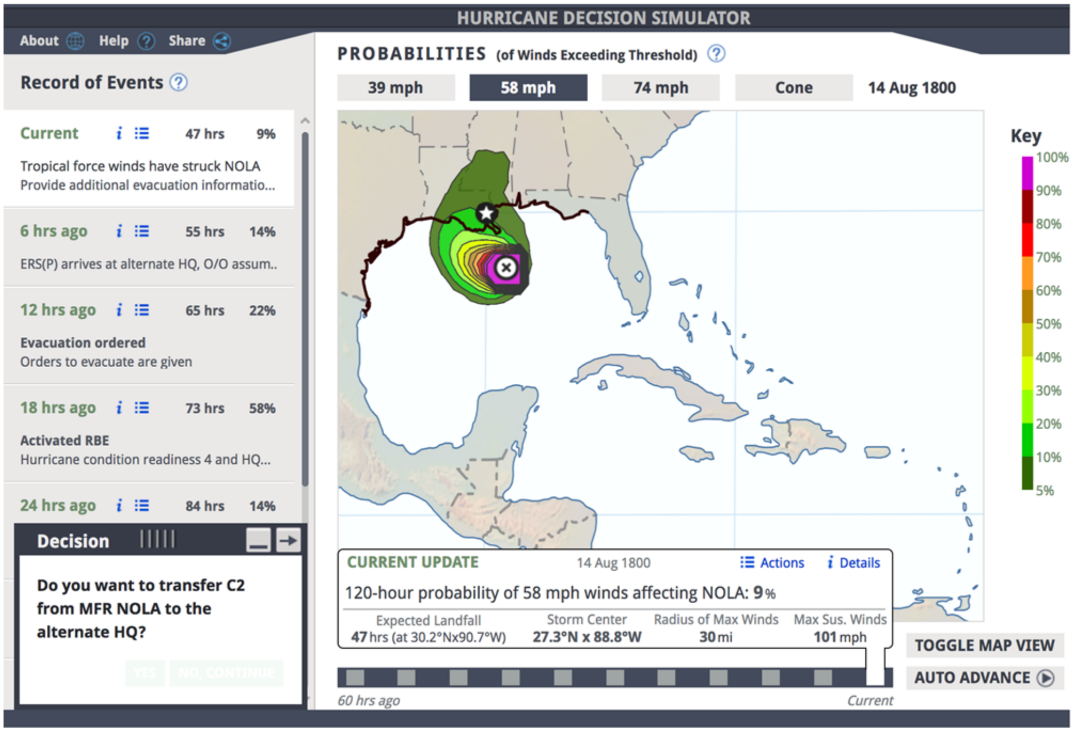


Figure 47. Thirteenth Update. Source: U.S. Marine Forces Reserve (2016).

After the thirteenth update, the user makes the decision to transfer C2 to the alternate headquarters based on a probability of 9% of receiving 58 mph winds at 47 hours before landfall, shown in Figure 47. This is the last decision the user is prompted to make. The user then proceeded through the fourteenth through seventeenth TC updates until the simulation is complete, shown in Figure 48 through Figure 51.

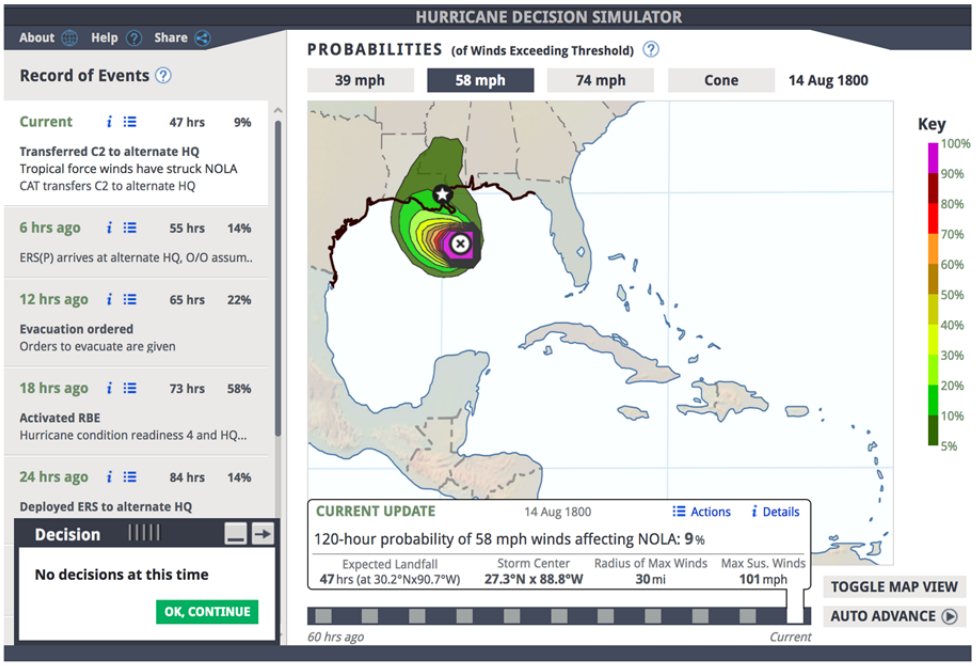


Figure 48. Fourteenth Update with C2 Transferred. Source: U.S. Marine Forces Reserve (2016).

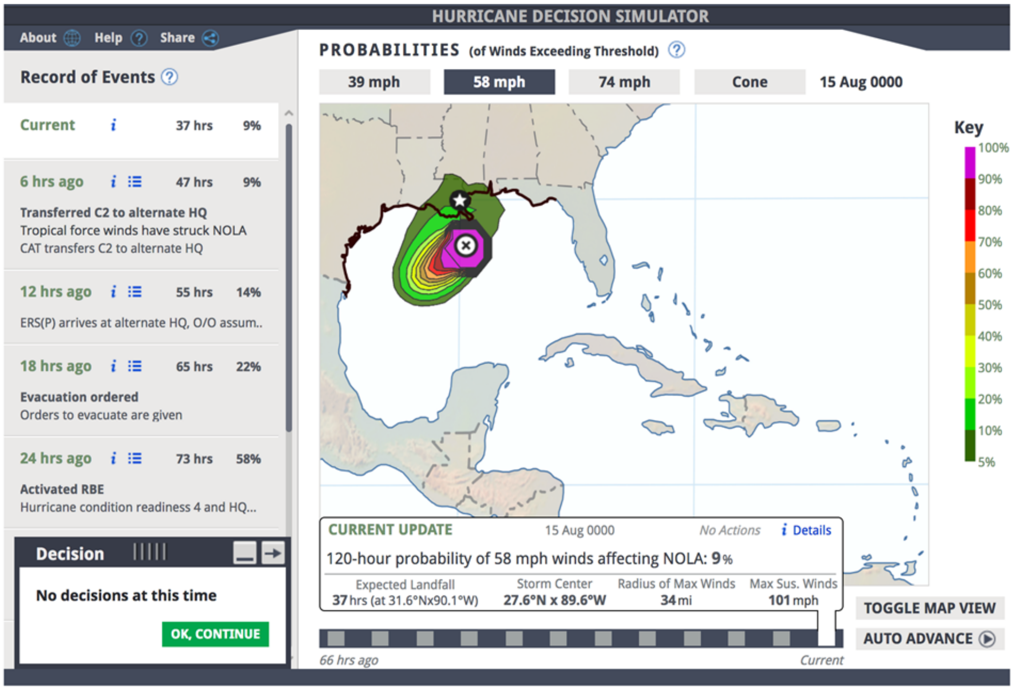


Figure 49. Fifteenth Update. Source: U.S. Marine Forces Reserve (2016).

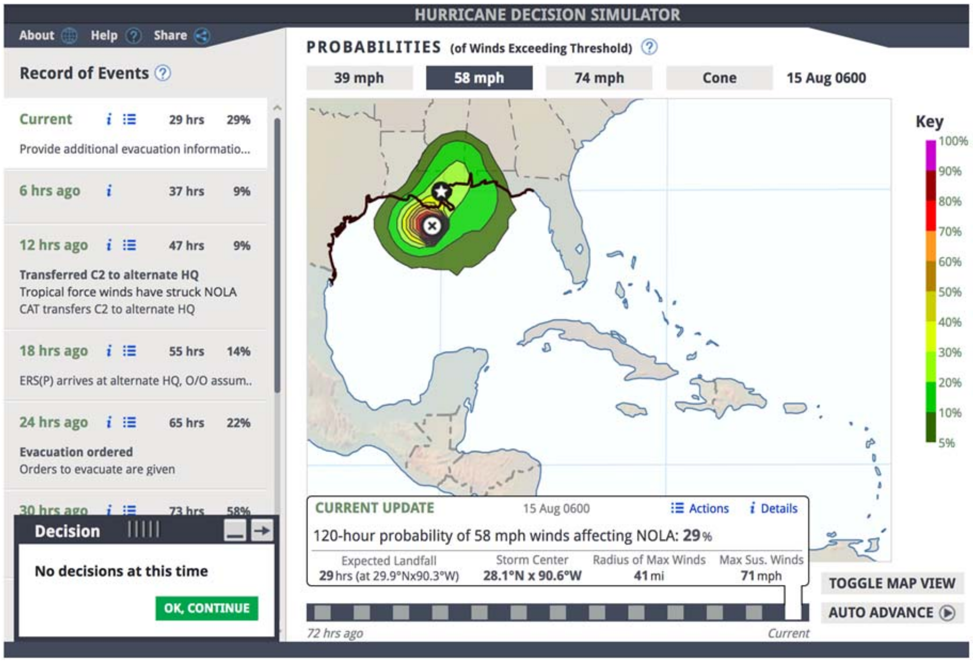


Figure 50. Sixteenth Update. Source: U.S. Marine Forces Reserve (2016).

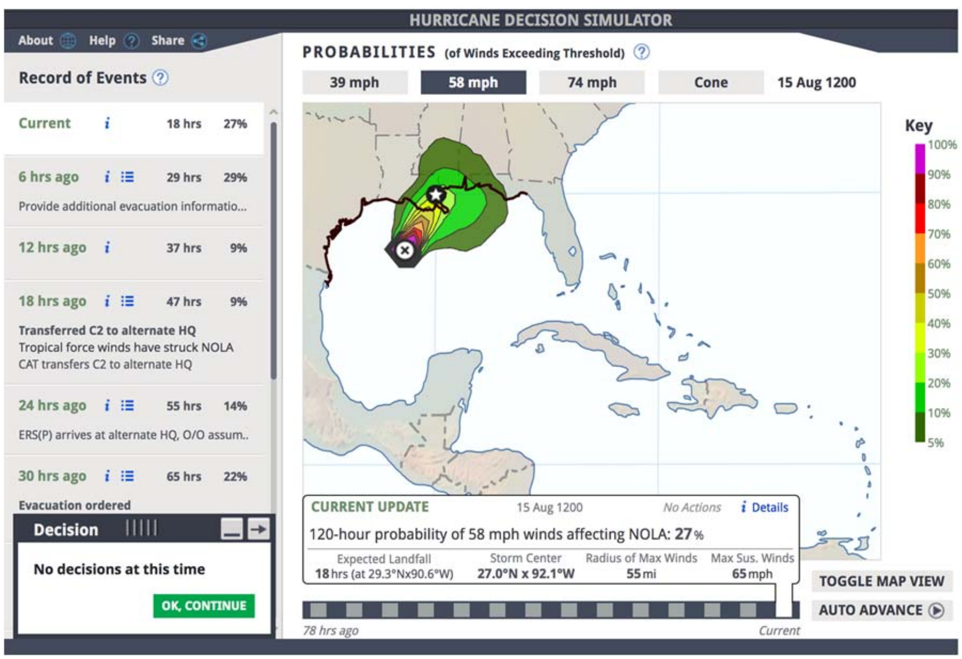


Figure 51. Seventeenth Update. Source: U.S. Marine Forces Reserve (2016).

After the simulation has concluded, the user receives the results, shown in Figure 52, and feedback, shown in Figure 53. The user can also review the entire simulation and analyze the TC and when he or she made decisions.

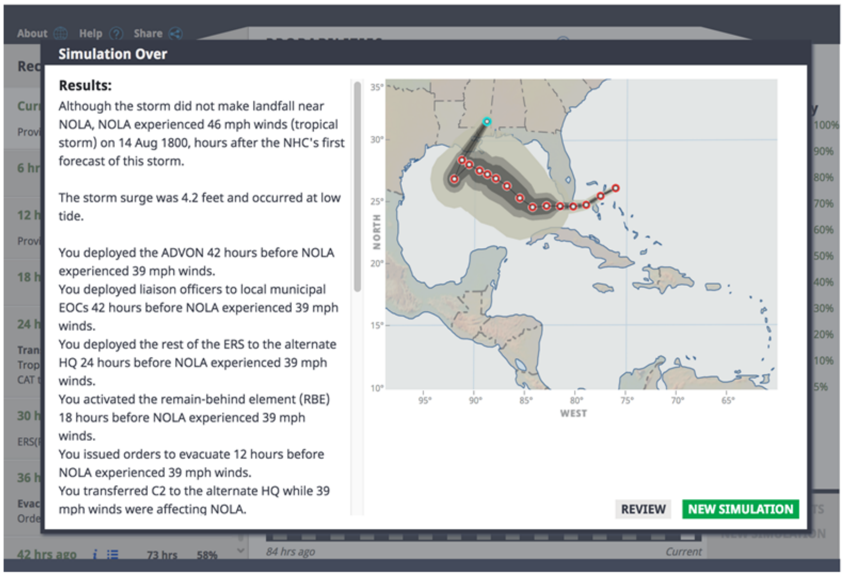


Figure 52. Simulation Results. Source: U.S. Marine Forces Reserve (2016).

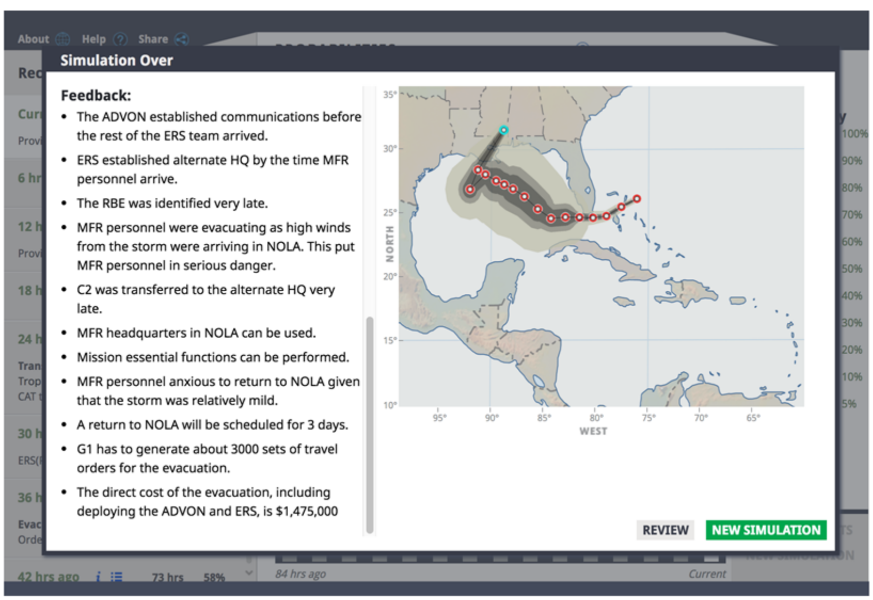


Figure 53. Simulation Feedback. Source: U.S. Marine Forces Reserve (2016).

SUPPLEMENTAL

The Database Support System Matrices include: actions, announcements, decision announcements, decision costs, decision storm, decision timing, decisions, surge results, and wind results.

The actions spreadsheet contains all the actions the MFRHTC must complete when a decision is made. The time and actions are recorded in the record of events and displayed in the feedback at the end of the simulation.

The announcements spreadsheet details announcements that pop up if the TC meets specified conditions based on wind cone probability, probability of wind speed, probability of surge level, and the expected TC time to landfall. If the specific condition is met, the time is recorded in the record of events, a pop up event is displayed and then is listed in the feedback at the end of the simulation. For example, announcements may describe actions by the MDOEM, or TC events like hurricane-force winds in Miami.

The decision announcements spreadsheet describes the announcements that pop as a result of the time when the user selects decisions in relation to announcements. For example, these describe any conflicts with local state, county, and MDOEM operations.

The decision costs spreadsheet details the fixed and variable cost of making each decision. Fixed costs are a one-time cost while variable costs are dependent on the wind speed and surge, which affect the duration of some activities such as an evacuation.

The decision storm spreadsheet describes the consequences of the time the user makes decisions in relation to the surge and winds conditions at the time. The events are listed in the feedback at the end of the simulation.

The decision timing spreadsheet specifies the conditions, announcement, and results in the event a decision is made too soon after an earlier decision. If a decision is made and the specified time has not elapsed, a pop up is triggered letting the user know the results of the decision at that time. The events are listed in the feedback at the end of the simulation.

The decisions spreadsheet contains the key decisions that the user is prompted to make in the HDS. When the user selects a decision, the time is recorded and information is sent to five interaction points. Depending on the time the user makes the decision and the position of the TC, announcements and popups may be triggered. The key decisions are detailed in the following section of this chapter.

The winds and surge spreadsheets specify the wind and surge thresholds with their associated decisions the MDOEM would make and other consequences. If the threshold is reached, the event is listed in the feedback at the end of the simulation.

Please contact the Dudley Knox Library if you are interested in retrieving the supplemental materials.

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